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ABSTRACT

A brief review of the characteristics of computer assisted instruction and the attributes of audiovisual media introduces this report on a project designed to improve the effectiveness of computer assisted learning through the incorporation of audiovisual materials. A discussion of the implications of research findings on the design and layout of print and the design and utilization of media for learning considers such topics as screen layout, use of media, still pictures, motion pictures, audio, feedback, scoring, and future developments in delivery systems and courseware. The remainder of the report provides detailed information on the computer hardware and random-access audiovisual devices used; the design and development of the computer program, including various subroutines and programming considerations; and detailed information on the various interfaces used. These include interfaces for the Revox Microfiche System with the DEC20, Cromemco System 3, Compucolor II, and Commodore PET; the SONY RX-353 with the Cromemco System 3, Revox Microfiche, Revox Audio, and Apple II; the Acorn Encoder with the Cromemco SDI; and the video switching interface. Diagrams are appended, as well as programs written in BASIC for a 9-part DNA replication. References are provided at the end of each of the introductory chapters. (LMM)

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REPORT ON RESEARCH PROJECT NO. P/24/1

IMPROVED COMPUTER-AIDED INSTRUCTION BY THE USE OF INTERFACED RANDOM-ACCESS AUDIO-VISUAL EQUIPMENT

C.F.A. Bryce
and
A.M. Stewart

IR010688

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Setting the Scene

Introduction

Various writers have identified a range of applications for the computer in instruction, including

- testing and scoring
- drills and practice
- tutorial programs
- simulations, games, problems.

For one of the authors of this report, an early experience in computer-assisted learning combined at least two of these applications. At the Texas Christian University, Fort Worth, in 1968 he went through several programs in organic chemistry. At first sight, they seemed to be simulations of laboratory experiments: an unknown organic substance had to be identified through a series of standard laboratory tests. Having, during his student days, frequently spent many long hours in the laboratory trying, frequently unsuccessfully, to identify such compounds and not learning any organic chemistry in the process, he realised the tremendous potential for computer-assisted learning, which, at that time, enabled him to 'analyse' several compounds in a relatively short time and, through the feedback provided by the computer when he suggested the wrong test or wrongly interpreted the results of the test, learn quite a lot of organic chemistry which he had forgotten (or probably never knew!). And the teacher obtained, through the computer, an analysis of how each student had tackled a particular analysis and was able to identify areas of weakness.

Of course, there were problems. The material was presented entirely in print on a teletype terminal. Today, such a program is probably presented via the PLATO system which is not only screen-based and highly interactive but can be linked to a wide range of audio-visual devices.

It was through recognition of the potential for computer-assisted learning and the limitations of computer-based learning systems, and through recognition of the attributes of media-based systems for the presentation of stimuli for learning that the present research project was proposed. It was also recognised that whatever developments could be achieved had to be possible within the available computer and media systems currently operating in the schools and colleges of Scotland.

characteristics of computer-assisted learning

While Hooper (1975) identifies 'tutorial' and 'drill & practice', as the two classical manifestations of computer-assisted learning, and goes on to clarify computer-assisted learning as being, in general, teaching people *with* computers rather than *about* computers, other writers such as Kozman, Belle, & Williams (1978) include simulations, games, and problems within the CAL experience.

It has to be realised, however, that this range of learning activities involving the computer is an expression of the usefulness of the computer in meeting particular learning requirements. Just as it is probably unwise to artificially separate out cognitive, affective and psychomotor aspects of learning since all three are likely to be

involved in any particular area of study, so it is probably equally unwise to separate out the 'tutorial', 'drill & practice', 'simulation', and 'problem-solving' aspects of computer-assisted learning since, in many areas of study, all may well be required to bring about the desired learning outcomes.

In fact, there is considerable danger of regarding computer-assisted learning in terms of what the computer can do rather than in terms of a particular contribution to the type(s) of learning to be effected.

Not that the delivery system is unimportant; although learning psychologists and instructional designers tend to ignore the importance of hardware delivery systems, being of the view that it is theories of learning and instruction which really matter. The attributes of the delivery system do matter, but they have to be coupled with the available guidance regarding the achievement of different types of learning.

Bunderson (1981) has listed the kinds of computer-assisted instruction strategies which have achieved prominance in the past 20 years, coupled with the kind of performance objectives they are best suited to achieve.

Learning Objectives	CAI strategy
Memory or simple skills	Drill or generated practice
Concepts or rules	Tutorial, and Rule-example-practice
Integration of concepts and simple skills and problem-solving	Simulations – games

Clearly, the basic objective types are memory or simple skills; concept, rule learning, and principles; and the integration of skills, concepts and principles.

The computer readily copes with these types of learning as a memory objective is likely to involve presentation of a stimulus term, then a response term from the student through recognition or recall; a concept or rule learning objective will involve the application of a classification or procedural rule to previously unencountered instances; and an integration objective will involve an unencountered problem that requires selection from and integration of a number of concepts, rules, and principles.

Bunderson argues however, that additional intelligence can be added to these basic CAI strategies (Since Bunderson is working in the American situation he will usually refer to CAI, whereas in the UK, the term CAL is more usually accepted). For example, 'answer analysis' and 'feedback' can require more than the recognition of multiple-choice responses. Numbers, words, short phrases, or 'pointing' responses can be entered, with answer analysis routines recognising these responses as acceptable or not, and giving feedback messages prepared as appropriate. A somewhat higher level of feedback message, sometimes described as a 'help' function, which

will prompt the student in the semantics of the rule or principle being applied and model an expert algorithm or procedure for applying the rule or principle to the presented problem, has been found to be effective.

Theory-based diagnostics can provide 'help' to a deeper level. As Bunderson says

> "they do this by using a cognitive model of the expert and a representation of the common discrepencies of learners from the expert model. The intelligent, theory-based computer program then tries to diagnose what the student is doing wrong and prescribes remedial action." (p.102)

There does not seem to be any doubt that 'drill & practice' exercises have achieved the most widespread use: there is also little doubt that such exercises can be very effective in a variety of settings. Although there is considerable evidence of their effectiveness in producing performance gains, there is also evidence that improvement is restricted to performance skills. Conceptual understanding is not improved through such programs. When dealing with concepts and principles, other strategies need to be employed, such as the 'tutorial' strategy in which there is normally a branching structure which may include constructed responses. In the 'rule-example-practice' strategy, the authors prepare components such as definitions of concepts or statements of principles, examples of applying these, and provide practice in applying the rules to unencountered instances. In some instances, the learners are able to control the selection of components, aided by an 'advisor program' that is designed to help them learn to select wisely.

Simple simulations and games have been widely used and more complex simulations such as the medical diagnosis simulation-tutorial have proved to be very effective. The medical situation is not unlike the qualitative chemistry exercise referred to earlier. The 'unknown' is a patient exhibiting certain symptoms, and a branching program requiring decisions from the student and which also feeds back the consequences of wrong decisions or provides tutorial help, enables the student to carry out the diagnosis and conduct the appropriate patient management.

These mainstream strategies for replicating interactions are well proven and widespread: their main attributes were therefore adopted in the development of materials for this research project.

attributes of the media

During the past 25 years considerable effort has gone into the development of modularised, self-paced instructional materials, of which computer-assisted learning materials are only a relatively small part.

All kinds of printed materials and audio-visual materials have been developed and used as the bases for self-instructional systems, but the attributes of the media are not necessarily related only to their usefulness as presentational systems in self-instruction.

In addition to providing motivation and visual interest, many of the media can be extremely useful in effecting particular types of

learning. In another communication (Bryce & Stewart, 1981) the authors have reviewed the development of theories relating media to types of learning and learner characteristics; have compared these theories to every day practice; and have described a pragmatic approach to the optimal application of media characteristics for various types of learning and learner characteristics.

Anderson (1976) has related visual media with instructional objectives which could be summarised as follows:

OHP transparencies

cognitive objectives	psychomotor objectives	effective objectives
useful for teaching recognition of, and discrimination among, relevant visual elements	limited, but may be used to show positions prior to demonstration or practice	not applicable

slides/filmstrips

cognitive objectives	psychomotor objectives	affective objectives
can be used to teach recognition and/or discrimination of relevant visual stimuli can be used to teach rules, principles, and sequences of events	little, if any, application	when used in combination with audio-tape can carry effective attitude-changing material

film & video

cognitive objectives	psychomotor objectives	affective objectives
can be used to teach recognition and/or discrimination of relevant motion stimuli can be used to teach rules, principles, etc.	useful for modelling motion skills, particularly through use of time manipulation	particularly useful to create attitudes and emotions by the use of various effects

Thus, it is clear that audio-visual media can contribute substantially to the learning of concepts and principles, particularly in subject areas which have a high visual content.

However, as Bunderson (1981) points out

> "The greatest weakness of books and audio-visual media is that they are not able to replicate interactions and so cannot convey the tutorial aspects of the modelling of process; cannot provide trials with true feedback, scoring, records; and so on. They cannot in and of themselves provide diagnosis of individual needs nor coaching and counselling in their own use. These are forms of work that are becoming increasingly necessary in a delivery system. It would seem, then, that printed materials and audio-visual packages must be incorporated increasingly into total delivery systems capable of performing far more educational work." (p.100)

That is really what this research project is all about. It is an attempt to develop a powerful delivery system through the improvement of computer-assisted learning by the interfacing of random-accessed audio-visual devices.

Implications for the Research Project

In the development of materials associated with this investigation, recognition was given to the need to provide intelligent feedback including prompts to help the student work out correct relationships; the value of developing a profile of each learner's performance abilities in the areas of learning concerned and prescribing remedial treatment as required; and the appropriateness of matching, where necessary, student performance with 'expert' performance in a given situation. Additionally, cognisance was taken of existing research findings regarding the design and layout of print and the design and utilisation of media for learning.

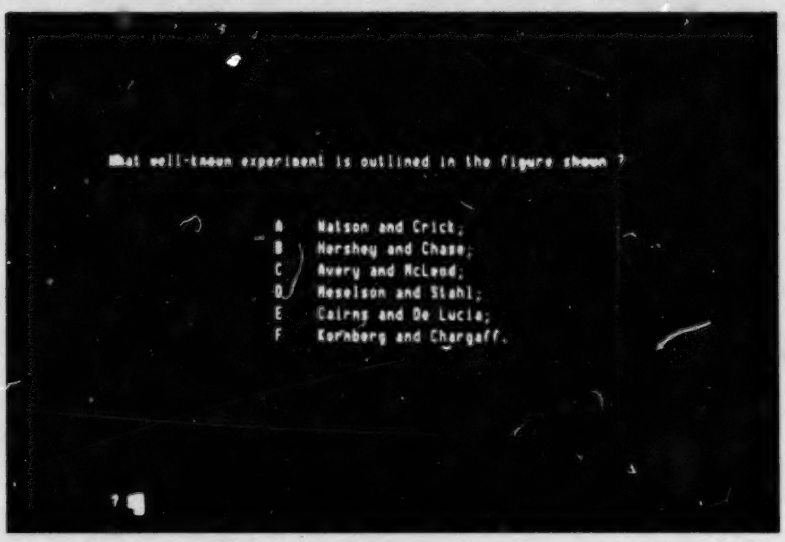
screen layout

The first thing to be considered was the availability of lower case letters on the VDU screen, as it has been clearly established that the legibility of lower case letters is much greater than that of upper case. It is most unfortunate that so many microcomputers, particularly the inexpensive units, make it very difficult to use lower case letters. The investigators were fortunate in having a particularly legible type face on the Cromemco 3102 terminal.

The size of the letter, the length of the line, and the spacing between the lines all contribute together to the legibility of the type. As the size of letter is unalterable and the space between the lines is fixed, the only variable available was the length of the line which, in the given circumstances, for optimal legibility was determined to be approximately 45 characters wide. Fuller information regarding legibility and layout of print, in general, is available in another communication (Stewart, 1981).

The program was written so that textual material, whether descriptive or interogatory, appeared in 'pages', with no distracting material falling off the screen.

The possibility of making keywords 'flash' or appear in inverse video was experimented with but, so far, no attempt has been made to determine the effectiveness of such presentation.


What well-known experiment is outlined in the figure shown ?
A Watson and Crick;
B Hershey and Chase;
C Avery and McLeod;
D Meselson and Stahl;
E Cairns and De Lucia;
F Kornberg and Chargaff.

use of media

One of the more unfortunate aspects of the audio-visual movement of the past 25 years has been a tendency to assume that the addition of visual material automatically increases learning with the result that many programmes have been produced, particularly tape-slide material, which could have been equally, or more, effective without the visuals.

The work of Dwyer (1978) and Fleming & Levie (1978) is particularly helpful when considering the incorporation of visual material.

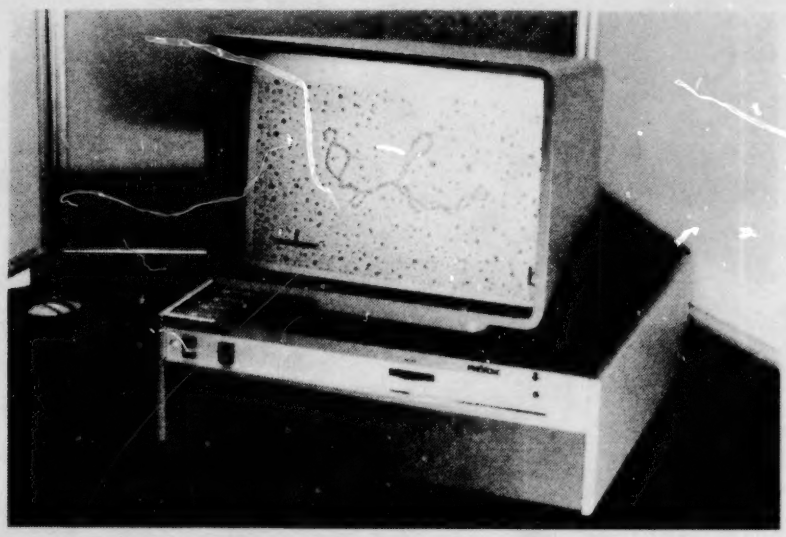
The investigators recognised the contribution which still colour visuals and motion picture or video systems could make to effective learning in the field of biochemistry and set out to develop a delivery system which would allow the exploitation of the attributes of the media without unnecessarily intruding in the learning experience.

☐ still pictures

Even the best of the so-called 'high resolution' graphics systems on microcomputers are incapable of presenting the kind of visual information required in the teaching of biochemistry, while the low-resolution systems (although never referred to by the manufacturers by that description) seem incapable of presenting anything other than something which looks as if it was built from Leggo.

The requirement in this project was for colour visuals of the quality normally associated with 35 mm colour slides. However, there was one problem – the images had to be randomly accessible. The most obvious choice was a random-access Carousel projector, but this was not adopted because of the cost of the equipment concerned and the fact that access times were slow.

The only alternative known at that time was a random-access microfiche system which was capable of displaying high quality colour visuals and which had a maximum access time (i.e. when visuals were diagonally opposite each other) of 0.7 seconds. Details of this system have been described elsewhere (Bryce & Stewart, 1979), but in the present context it should be noted that the system enabled the image to be on the screen only when it was required. The lamp could be extinguished (under software control) so that there was no possibility of distraction from an either unwanted or unnecessary visual.



☐ motion pictures

There are occasions in the teaching of biochemistry and, of course, many other subjects, when the availability of motion images is particularly helpful. At one time the investigators had experimented with film-based material (Bryce & Stewart, 1978) which allowed both still and moving images to be presented and which proved to be an effective presentation system for instructional purposes, but, like all film systems, it was not possible to randomly access the various parts of the film. Accordingly, in this investigation, video tape was chosen because it was possible to utilise a videotape player which could randomly access up to 63 segments of tape, albeit not particularly rapidly.

Again, under software control, the video segments were presented at appropriate points in the program. The student was given complete freedom to stop and start and, if necessary, replay or omit any section by operation from the computer keyboard.

☐ audio

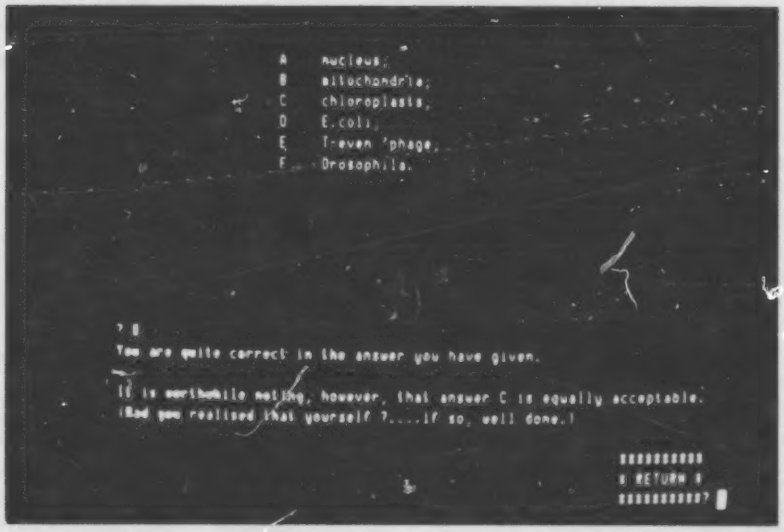
Inevitably in the presentation of instructional sequences there is a considerable amount of verbal material. Where this tends to be descriptive or, perhaps, discussion without the need for new keywords to be recognised, there could be advantage in presenting via audio-tape rather than on screen. Accordingly, it was decided to develop a random-access audio system which could be under software control. Although it is rather early to comment on the effectiveness of such an approach in this instance, clearly such an approach could be particularly useful where sound discrimination may be necessary.

feedback

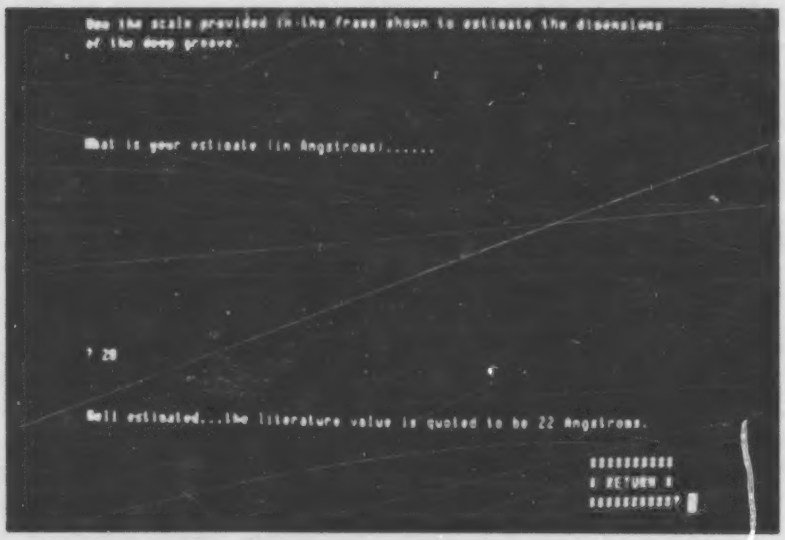
All the evidence suggests that feedback of an intelligent nature should be given throughout a program. For this project, feedback was given after every response, whether the response was right or wrong.

The program was designed so that students were required to respond in a variety of ways: by indicating the right answer to a multiple choice question; by providing a free word answer; and by typing in a numerical response.

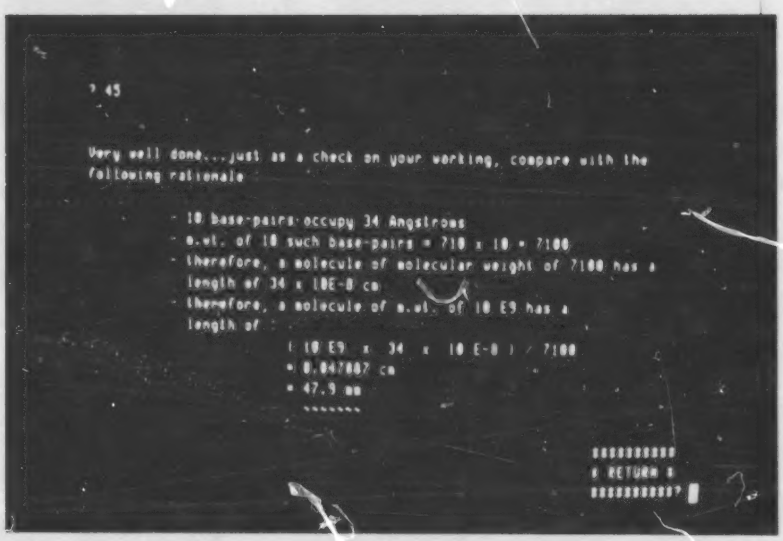
Frequently, in multiple choice questions, more than one response could be correct, in which case the student would be informed, if correct, that his response was acceptable but he was reminded of the other acceptable responses.



Where numerical responses were required, the program was designed to accept either an exact response where necessary or an answer within prescribed limits. In each case, comment would be made upon the student's response.


Use the scale provided in the frame shown to estimate the dimensions of the deep groove.
What is your estimate (in Angstroms).....
? 20
Well estimated...the literature value is quoted to be 22 Angstroms.
RETURN
?

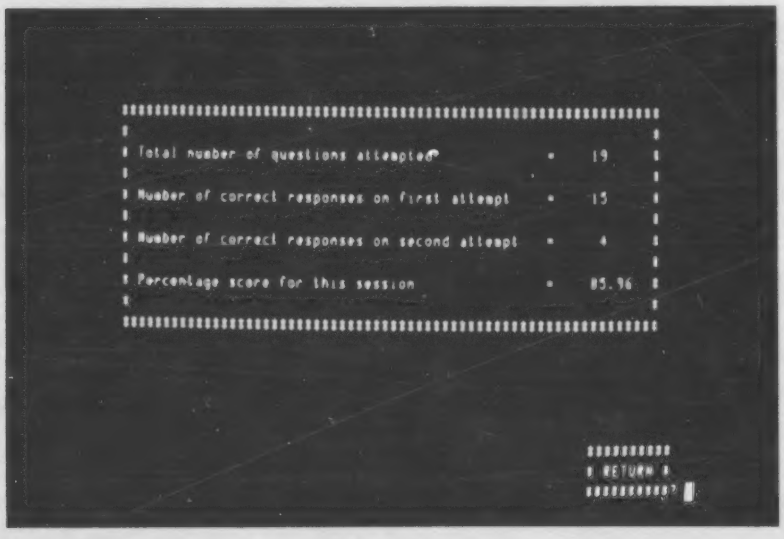
If the student was required to be involved in a quantitative exercise, the feedback provided would take him through the derivation to ensure that the 'correct' process as well as the correct answer was known.


? 45
Very well done...just as a check on your working, compare with the following rationale
- 10 base-pairs occupy 34 Angstroms
- a.wt. of 10 such base-pairs = 710 x 10 = 7100
- therefore, a molecule of molecular weight of 7100 has a length of 34 x 10E-8 cm
- therefore, a molecule of a.wt. of 10 E9 has a length of
(10 E9 x 34 x 10 E-8) / 7100
= 0.047887 cm
= 47.9 mm
^^^^^^^
RETURN
##########?

In all cases, it was decided that, if the student was unsuccessful after a second attempt at a question, he would be automatically taken on to the next section of the program.

scoring

As part of the feedback mechanism, the programs were designed so that the student could, at any point in the program, request his current performance in which case the VDU would indicate how many questions he had answered correctly at the first attempt and at the second attempt, how many he had failed to achieve, and his percentage score at that point.


Total number of questions attempted = 19
Number of correct responses on first attempt = 15
Number of correct responses on second attempt = 4
Percentage score for this session = 85.96
RETURN
##########?

At the end of the program the student is given this information in a different form, relating achievement to the learning objectives for the program. A printout, carrying the student's name and class, indicates the objectives achievement of which he had

demonstrated mastery, the objectives with which he appeared to be uncertain, and the objectives which he had clearly not achieved. This type of feedback could be usefully supplemented by provision of guidance for further study but, to date, this has yet to be done.

In this way, a profile of the student's performance is being compiled and the information is transferred to a management file so that the teacher can, at any time, check on the performance of students and identify those areas of the topic which appear to be presenting difficulties.

Future Developments

Educational technology is a dynamic process operating within a dynamic educational milieu. Inevitably, therefore, developments will occur in the delivery systems and in the courseware associated with computer-assisted learning.

delivery systems

There are probably three aspects of the delivery system which are likely to change; the input mechanism, the processing unit, and the information presentation features.

- ☐ input

Although there have been experiments with alternatives to the standard keyboard input mechanism, in particular with units requiring only five finger manipulation, the keyboard is still very firmly established as the main input mechanism and its use is so widespread that it is unlikely ever to be completely replaced.

Nevertheless, its operation does require a degree of skill which is not attainable by many potential users of computer-assisted learning and alternative means for inputting need to be investigated.

Perhaps the system with most potential will be a 'touch-sensitive' system in which a number of areas of the screen will be, in effect, keys whose function can be varied under software control. Although touch sensitive systems are already available they are rather expensive (around £500 for an add-on kit and as much as £1700 for what is, in effect, an intelligent terminal). The potential of touch-sensitive input systems would justify the development of a less-expensive and probably less elaborate mechanism.

However, the existing elaborate systems offer considerable potential for more ambitious utilisation of computer assisted learning and investigations based on the courseware for the present project are currently being pursued.

- ☐ processing unit

Although all the major computer-assisted learning projects have been carried out with mainframe or mini computers, usually on a time-sharing basis, indicators for future development are undoubtedly in favour of small stand-alone microcomputers available to the individual student or, perhaps, even owned by him.

The availability of 32-bit processors will probably be helpful and utilisation of dual or even multi processors within a microcomputer should enable very much faster processing. Such equipment is already coming on to the market.

□ presentation

There are serious problems associated with the presentation on one screen of video material generated by the computer and by a standard video recording system, although equipment such as the new Sony microcomputer seems to have overcome the difficulties which are, essentially, related to synchronisation.

The availability of the reflective video disc (e.g. Philips Laservision) opens up totally new areas for the integration of video and CAL because the 54,000 individual frames on each side of the disc can be rapidly accessed and can provide a single still picture of high quality or, in normal running mode, a moving picture of a quality which far surpasses that available with video-tape systems.

The present investigators are currently involved with developments in this field and the interfacing of a domestic video disc player with the microcomputer is already at an advanced stage.

courseware

Fields and Paris (1981) have claimed that hardware and software technology development is far in advance of instructional strategies development, citing the fact that instructional strategies, which determine the educational effectiveness of CAL systems, have not shown any dramatic improvement over the past 20 years.

Nevertheless, as pointed out earlier, there have been attempts to develop materials which are considerably more 'intelligent' than those used in the earlier days of CAL. The PLATO and TICCET systems in the United States have certainly attempted to exploit CAL at a fairly high level, and the present project has made every attempt to avoid low-level operation.

It is likely that one of the major advances in computer-assisted learning over the next five years will be the development of program materials which will be more 'intelligent' in the simulation of a performance environment through the model of an expert performer with conceptual domain knowledge that shows understanding of the concepts and relationships between concepts in the domain and with procedural knowledge that guides performance of relevant tasks in the domain; in the provision of a diagnostic model of the learner's status in which comparison is made to the procedural model of the expert's performance and discrepancies noted; and by the development of a prescriptive model for how to tutor a given individual.

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Hardware

computer hardware

The Learning packages described in the present study were developed for both a main frame computer (DEC SYSTEM 2050) capable of supporting 64 simultaneous terminal users with a typical workload (present configuration, 512K 36-bit word main memory, PDP 11 front-end communication processor, 400 Mbyte disk storage on two RPO6 drives with separate channels) and also a stand-alone micro-computer system, a Cromemco System Three (64K RAM, dual disk drive each taking 512K 8" diskettes). The Cromemco system was used with a high capacity CRT terminal (Model 3102) and a high quality daisy thimble printer (model 3355A). A TU-ART digital interface with two serial input/output ports and two 8-bit parallel input/output ports was assembled on the S-100 bus of the micro-computer. The interfaces designed in the present study were also implemented using a Commodore PET microcomputer, a Compucolor II microcomputer and an Apple II microcomputer.

audio-visual hardware

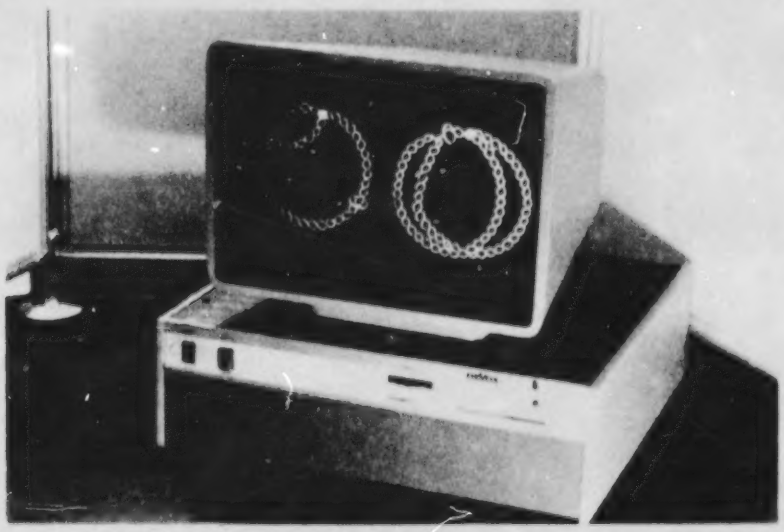
The random-access back projection system employed was the Revox Audiocard System (Revox ELA AG, Zurich, Switzerland) which utilises a 60 image (5 x 12 grid) microfiche positioned on a DIN A6 card measuring 11.5 x 16.75 mm. The equipment supplied commercially is accessed by use of a control device or encoder. Instructions can be given via this encoder to fade out/in the light source, move to another image or illuminate either the left hand or the right hand side of the screen alone.

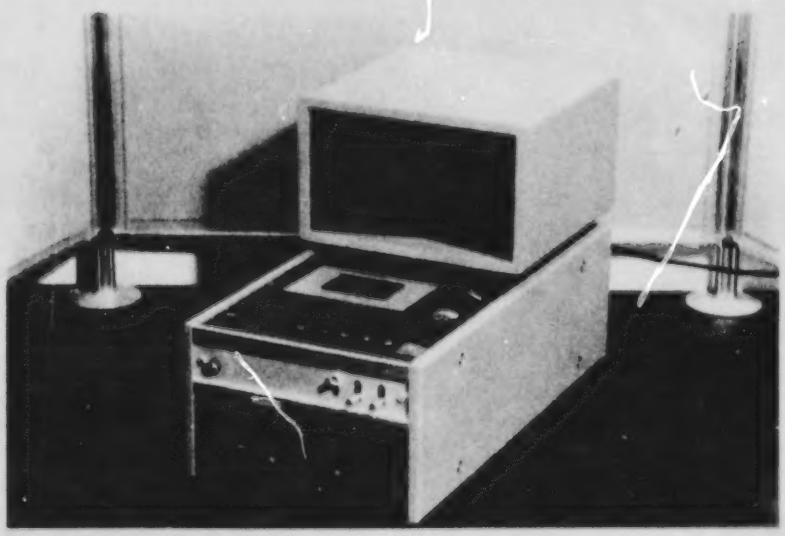
The random-access audio employed in the study was also manufactured by Revox and was the D88 cassette recorder.

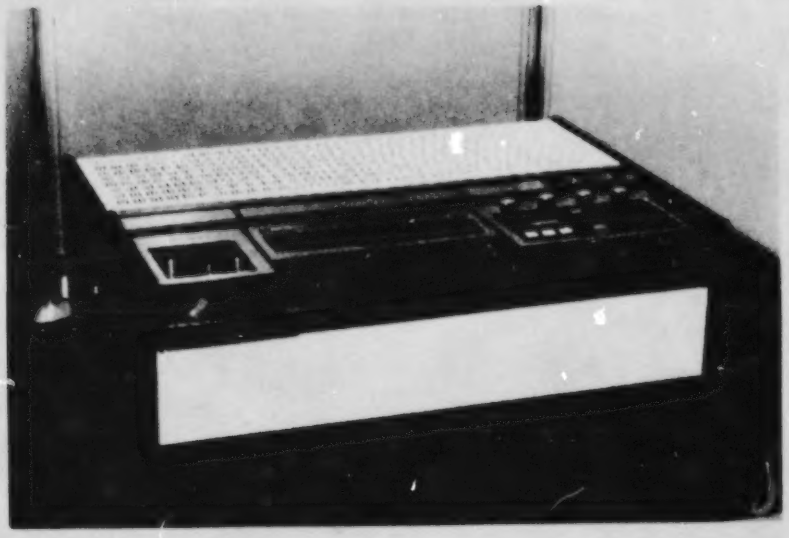
The random-access video utilised was a Sony U-matic (Model VO-2860) which was controlled by use of an auto search control (RX-353CE). The auto search control is designed to quickly locate any desired point on the videocassette tape, and start playback from that point. The segment data, up to 63 different segments, memorized by the control unit were recorded on the videocassette tape and this information served as a permanent record which could be accessed at later dates.

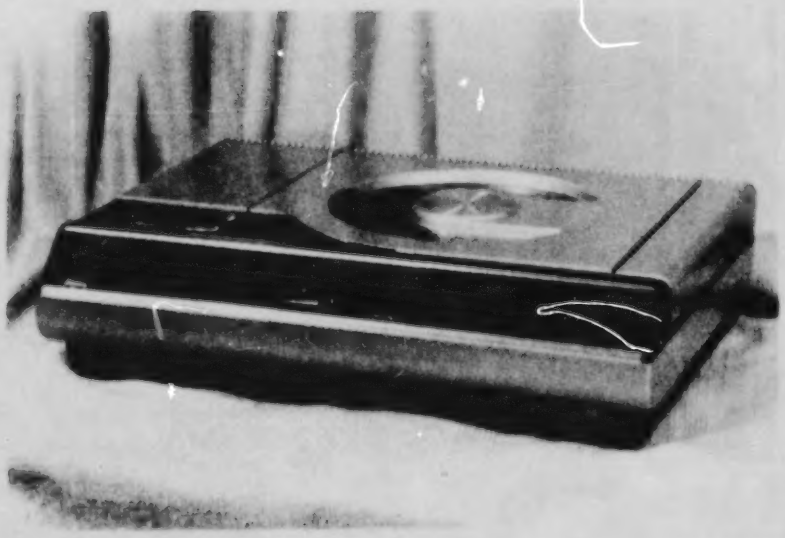
In order to create an Audiocard master microfiche, it is necessary to use a special camera system, the ALPA Master-System. Owing to the high cost of such a specialist piece of equipment, we did not feel that the amount of projected use warranted its purchase and so our microfiche were produced commercially from 35 mm slides (Fogarty Colourfiche, London). During the production of the microfiche, a filmstrip is obtained as an intermediate with each 35 mm original slide being copied with contrast control and colour correction. The consequence of this procedure is that the final microfiche can, if required, be a complete mixture of black and white, full colour, lith negative and coloured lith images, each one having the correct photographic exposure.

The following figures illustrate the individual components and the system together with a module of the complete system.









Software

computer software

During the design of the computer program we were mindful of the research associated with the optimal conditions for legibility and lay-out both for textual and visual material. Aspects such as question formatting, setting page size, appropriate feedback, allowable error range in quantitative problems, current status accessing etc. have already been described in earlier communications [Bryce and Stewart, 1979; Bryce, 1981; Stewart, 1981; Bryce and Stewart, 1981].

Owing to the considerable amount of textual information contained within many of the computer-based programs together with the facility for appropriate program branching etc., they occupy fairly large amounts of memory, of the order of 100K or more. Using the main frame computer there is no problem associated with the need for this amount of memory but this is not the case with the micro-computer system. Our own system has 64K RAM and, of this, approximately 32K is used in storing the extended BASIC plus the operating system. This being the case, our 100K learning packages are structured as 30K units, any number of which can easily be chained to cover the entire program. For the present study, however, it is important that certain run-time information (number of questions attempted, current score, time taken, objectives met etc.) is transferred during the chaining operation from one unit to the next and this is achieved as shown in Figure D.1 below:

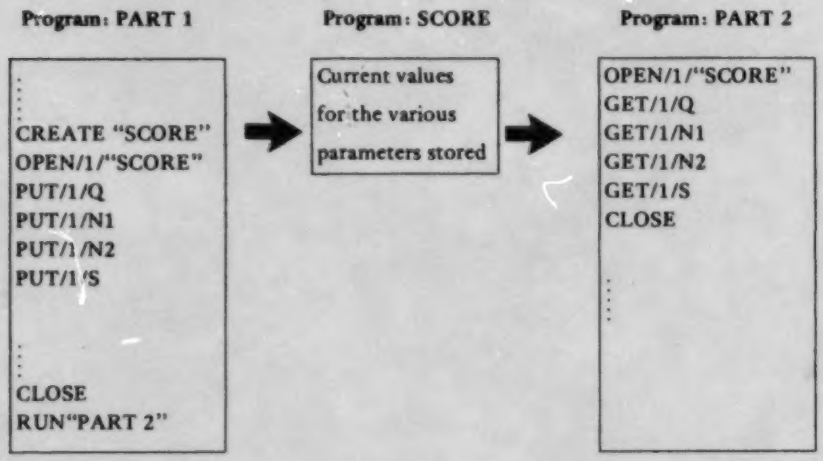


Figure D.1 Program chaining in 30K units using the SCORE program (1K) to transfer certain run-time information from one unit to the next.

Thus, the PUT instructions in the program PART 1 transfer the current values for the different variables Q, N1, N2 and S into a small program called SCORE from which these values can be accessed by GET instructions from another program, in this case PART 2.

The following sub-sections deal with aspects of the software used in the improved computer-based learning system described in this study with the exception of the software used to drive the various audio-visual devices. This latter topic will be considered in considerably more detail in the following section which deals specifically with the design, construction and implementation of the associated interfaces of the system.

subroutine to evaluate the assessment data

In this particular package we decided to allow the student a maximum of two attempts at each question. If he/she was correct on the first attempt, the current value of the score (S) was incremented by 1 and the number of questions answered on a first attempt (N1) was similarly incremented. If he/she was correct on the second attempt, the current value of the score was incremented by one-third of a point and the number of questions answered on a second attempt (N2) incremented by 1. The flag used to decide whether the answer was a first or second attempt is given by the value of T. At the beginning of each question, the value of T was set to zero. If the answer was incorrect, T is incremented by 1 and the question then represented to the user provided T=1 otherwise the user was directed to another question. The total number of questions attempted (Q) is incremented at the start of each question. Another parameter which was dealt with in this subroutine is the array O(N) which related the different questions to specific learning objectives stored on a disk file. The handling of this information is considered in a later sub-section. The software for evaluating the assessment data is as follows:

```
200       LET T=0
210       GOSUB 10000

          Instructions for printing the question
          on the VDU screen


400       GOSUB 20000

10000     REM ********************************
10010     REM
10020     REM  Subroutine to evaluate the
10030     REM  number of questions and attempts
10040     REM
10050     REM ********************************
10060     REM
10070     LET T=T + 1 : IF T=1 THEN 10090
10080     RETURN
10090     LET Q=Q + 1 : RETURN

20000     REM ********************************
20010     REM
20020     REM  Subroutine to evaluate the
20030     REM  assessment data
20040     REM
20050     REM ********************************
20060     REM
20070     IF T=1 THEN 20120
20080     LET S= S + 0.33333
20090     LET N2 = N2 +1
20100     LET O(N) = 0.5
20110     RETURN
20120     LET S = S + 1
20130     LET N1 = N1 + 1
20140     LET O(N) = 1
20150     RETURN
```

subroutine to output assessment data

In designing this package we felt that it would be advantageous for the student to be able to monitor his or her own performance at any point in the package. To do this, the student need only type the letter S (for score) at any point in the program where a RETURN is encountered. A typical outcome of this request is shown below:

```
*****************************************
*                                       *
*  total number of questions attempted      = 45    *
*  number of correct responses on first attempt  = 36    *
*  number of correct responses on second attempt = 3     *
*  percentage score for this session        = 82.22  *
*                                       *
*****************************************
```

Once this information is assimilated, the user is returned to the correct part of the program in order to continue with the lesson.

The subroutine uses the current values of the variables Q, N1, N2 and S which were described earlier and the software is as follows:

```
85000  REM Subroutine for outputing assessment data
85010  For N = 1 to 10
85020  Print
85030  Next N
85040  Print Tab (5);"* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *"
85050  Print Tab (5); "*";
85060  Print Tab (67); "*"
85070  Print Using" * Total number of questions attempted = ### *",Q
85080  Print Tab (5);"*";
85090  Print Tab (67); "*"
85100  Print Using"* Number of correct responses on first attempt
       = ### *", N1
85110  Print Tab (5); "*";
85120  Print Tab (67); "*"
85130  Print Using" *Number of correct responses on second attempt
       = ### *", N2
85140  Print Tab (5); "*";
85150  Print Tab (67); "*"
85160  Print Using" * Percentage score for this session = ### ## *",100*S/Q
85170  Print Tab (5); "*";
85180  Print Tab (67); "*"
85190  Print Tab (5); "* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *"
85200  For N = 1 to 5
85210  Print
85220  Next N
85230  Return
```

subroutine to output detailed final assessment analysis

Before entering the subroutine to evaluate the assessment data, each question is related to a specific learning objective by assigning a value to a variable N. This value was used to select an element of the array O(N) and then assign to it a value of 1, 0.5 or 0 depending on whether the question was answered correctly on the first attempt, correctly on the second attempt or incorrectly.

If, at the end of the session, the value for O(N) was greater than 0.8 the student was deemed to have mastered that particular objective. If the value lay between 0.5 and 0.8 the student was informed that they had struggled in part with that objective. If the value was less than 0.5 they were informed that they had difficulty grasping that particular objective. Also output was the numeric score for the session as described earlier. The detailed analysis was output on the line printer which was connected in parallel to the microcomputer.

The instruction to switch on the printer for the analysis was given by PRINT CHR $ (23). With the Cromemco 16K Extended BASIC the single character @ can replace the PRINT instruction. An example of the type of output is given below.

Student name. . . . .C.F.A. Bryce

Class. . . . . .Test Run

The following represents those learning objectives which you have clearly mastered:

– distinguishes between linear and cyclic DNA as seen in electron micrographs
– distinguishes between the deep and narrow grooves in duplex DNA
– evaluates the dimension of the deep groove of DNA from data supplied
– identifies the characteristic diffraction pattern derived from a helix
– distinguishes between those spots on an X-ray diffraction pattern corresponding to low and high resolution experimental data
– calculates the length of a DNA duplex given the molecular weight of the DNA and the molecular weight for an 'average' base pair
– illustrates the significance of intramolecular base pairing in single-stranded RNA to the physical properties of the RNA molecule
– distinguishes between a wide variety of tertiary structures for DNA
– evaluates the contour length for a given DNA molecule from EM data
– identifies the unique tertiary structure of DNA isolated from mitochondria and chloroplasts
– distinguishes between semi-conservative replication and other plausible modes of replication
– describes the key features of the Meselson and Stahl experiment
– describes the procedure and rationale of density gradient centrifugation using CsCl
– states the value of the characteristic absorption maximum for DNA
– distinguishes between the terms first generation and second generation as applied to replication
– predicts the sequence of a DNA strand which is complementary to a given segment of DNA
– describes the three peculiarities of the product obtained on incubating native double-stranded DNA with DNA dependent DNA polymerase I
– describes the experimental evidence against the replicase role for DNA polymerase I
– identifies the functional role for Okazaki fragments during replication
– distinguishes between discontinuous and continuous DNA strand synthesis
– describes the experimental evidence for the view that DNA synthesis occurs bidirectionally
– describes the role of multiple initiation sites during replication
– distinguishes replication bubbles from other DNA tertiary structures
– identifies multiple replication bubbles in an electron micrograph
– distinguishes a replication bubble from a appearance of loops in electron micrographs
– identifies replicating cyclic DNA in electron micrographs
– states that cis-A protein acts as a specific endonuclease in DNA replication
– states the key features of the rolling circle model for DNA replication
– identifies a DNA molecule exhibiting rolling circle replication

- outlines the steps involved in the replication of a closed-cyclic DNA duplex
- describes the origin and fate of superhelical twists during replication of of closed-cyclic double-stranded DNA
- outlines the mode of action of the enzymes that take part in butterfly replication
- outlines the steps in the repair process for uv-irradiation damaged DNA
- describes the mechanisms for DNA repair

The following represents those learning objectives which you have struggled with in part:

- identifies nucleic acid within an electron micrograph
- distinguishes between supercoiled DNA and relaxed cyclic DNA
- states that DNA replication occurs by a semi-conservative mechanism
- outlines the nature of the banding pattern obtained in the Meselson and Stahl experiment

The following represents those learning objectives which you are very clearly finding difficult to grasp:

- distinguishes between A-form and B-form DNA
- states the number of base pairs found in B-form DNA
- identifies the relationship between the viscosity of a solution of DNA and the physical structure of the DNA molecule

Total number of questions attempted	= 51
Number of correct responses on first attempt	= 36
Number of correct responses on second attempt	= 12
Percentage score for the assessment session	= 78.43

The software used to manage this information is illustrated in Part 9 of the total package (see Appendix 1).

If required, it is also possible to store each user's final assessment scores etc on disk. When the user types in his/her name in response to the question in Part 9 of the program the software can take this character string (U$) and create a data file with this string as its name (or at least the first eight characters of the string) and store this on the disk. In this way it is possible for the lecturer to analyse the individual student performances together with that of the class as a whole and so identify any weak areas or difficulties. The software used to open a data file with a run-time label is shown over:

```
10  REM ********************************
20  REM
30  REM  Procedure for opening a data file with run-time label
40  REM
50  REM ********************************
60  ON ERROR GOTO 150
70  REM
80  REM  In naming the data file, the operating system takes only the
90  REM  first eight characters of the character string
100 REM
110 U$ ="Charlie Bryce"
120 S=23
130 T=45
140 CREATE U$
150 OPEN/1/U$
160 PUT/1/S,T
170 CLOSE
180 END
```

subroutine to print the ****** *RETURN* ******** box**

One problem in using a VDU terminal is that frequently the output is longer than can be accommodated on the screen and so material runs off the screen before the user has a reasonable chance to read and digest the information. This can be easily overcome by using a systems command of the type:

@ TERMINAL PAGE 20

which, on the DEC-20, would stop the output after 20 lines of information. Once the information is read the output can be continued by typing in certain key instructions, eg **CONTROL/Q.**

We have used this approach for some programs in the past but, in practice, this has given rise to a considerable number of problems with students as multi-users. This being the case, a sub-routine was incorporated into the present program which would carry out an identical function, ie it would not allow output to run off the screen before the user had a chance to read it. The sub-routine in use generates the grid box with the word **RETURN** in the centre. Once the student has assimilated the material he or she can continue by depressing the **RETURN** key on the VDU keyboard. This particular sub-routine has additional functions written into it and these are as follows:

– type **S** before depressing return to obtain the current score

– type **B** before depressing return to allow the user to have a break. After typing in the length of time required for the break, the software disables the keyboard for that time interval such that no other user can interupt the program.

– type **Ø** before depressing return to exit from the program

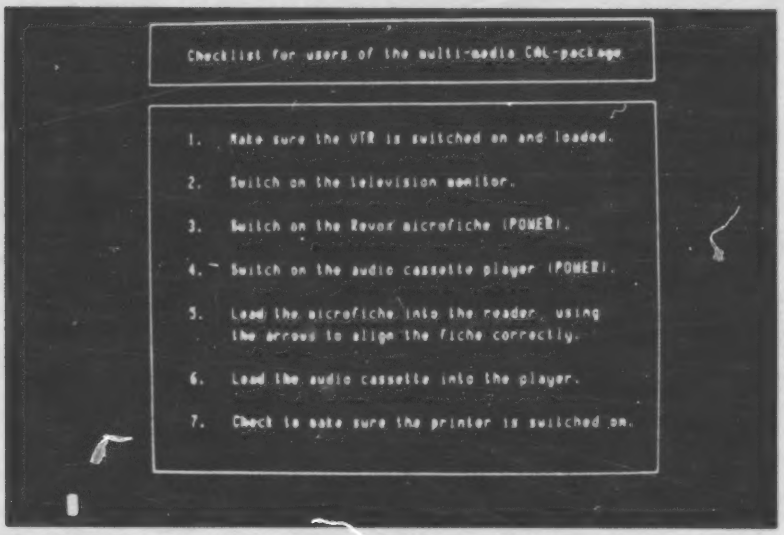
– type **P** before depressing return to interupt the audio sequences

automatic startup and program execution

A very powerful feature of the Cromemco Disk Operating System (CDOS) is the ability to enter directly into an application program when powering up the computer. This is especially useful for the inexperienced user as there is no need to deal with any of the commands which are used to load and execute a program.

The floppy disks used by the students were modified in such a way that as soon as the CDOS was booted (type B), the program STARTUP.CMD loaded the batch command file @.CMD which in turn loaded 16 K Extended BASIC plus the applications program ENTRY.SAV.

The program ENTRY.SAV functioned as a checklist for the user as shown in the figure below:


Checklist for users of the multi-media CAL-package
1. Make sure the VTR is switched on and loaded.
2. Switch on the television monitor.
3. Switch on the Revox microfiche (POWER).
4. Switch on the audio cassette player (POWER).
5. Load the microfiche into the reader, using the arrows to align the fiche correctly.
6. Load the audio cassette into the player.
7. Check to make sure the printer is switched on.

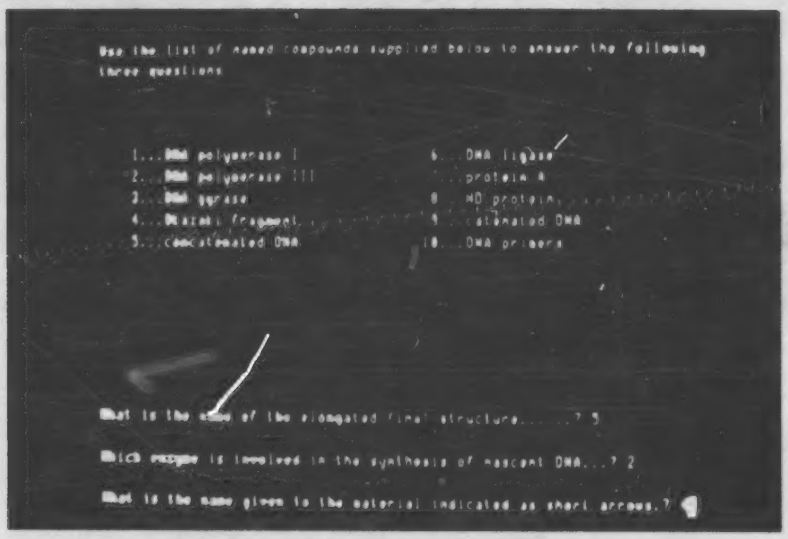
Whilst the user was reading the checklist, the software was initialising the video-tape recorder to locate the first required segment of video and to switch off the television picture once this was correctly located.

The entire software package includes the files ENTRY.SAV, PART1, PART 2, PART 3, PART 4, PART 8, PART 9 and SCORE together with a run-time created file on the user's performance. The total disk space used by the applications package is 124 kilobytes (124 K) of memory.

additional software considerations

Typical formats for the test items within the program are shown below, with single answers or multiple answers being accepted.

From which source would you be most likely to extract the DNA as shown in the frame shown.
A nucleus.
B mitochondria.
C chloroplasts.
D E.coli.
E T-even phage.
F Drosophila.


Use the list of named compounds supplied below to answer the following three questions
1...DNA polymerase I
2...DNA polymerase III
3...DNA gyrase
4...Okazaki fragment
5...concatenated DNA
6...DNA ligase
...protein A
8...HD protein
9...catenated DNA
10...DNA primers
What is the name of the elongated final structure.....? 5
Which enzyme is involved in the synthesis of nascent DNA...? 2
What is the name given to the material indicated as short arrows.?

The student responds by typing in the letter of his or her choice. This is checked by character or string matching and an appropriate message is output to the VDU. Examples of such diagnostic feedback are shown below:

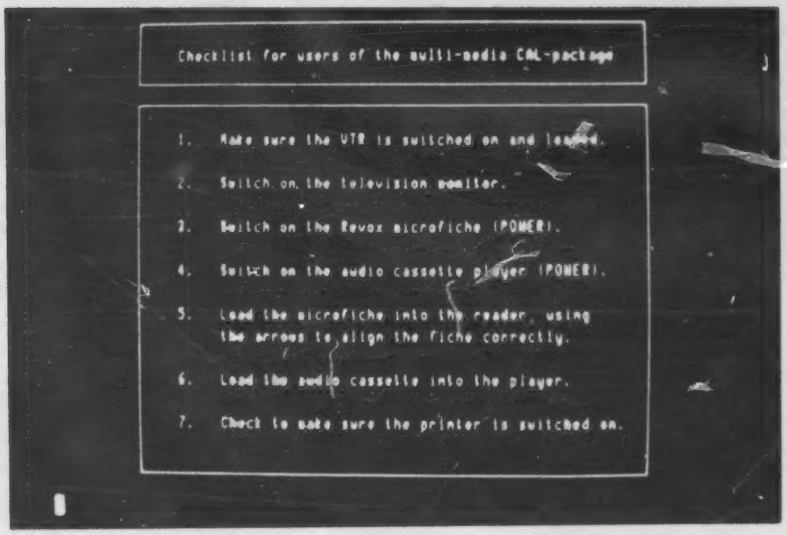
'Well done. . . The X-shaped pattern is not too clear in this particular diffraction pattern. The reason for this in this case is because the fibres used were not very highly ordered.'
"Yes, well done. The distinction between deep and narrow grooves is very important when we come to consider enzyme-binding to DNA and also the binding of certain antibiotics.'
'No wrong answer . . . Try again, this time look to see if the base pairs are at right-angles to the backbone. This should help you to distinguish between the different possible forms.'

During the program's development phase it became obvious that the system was well suited to operate in a tutorial mode in that questions plus associated visuals could be presented and, equally easily, factual accounts and their associated visuals could be presented to the students. This we used to convey either additional material or remedial material to particular groups of students.

Quantitative problems could also be managed with ease. In developing the program, it was a simple matter to incorporate a tolerable and pre-specified error in any such quantitative estimate — thus one might allow a student an error of 10 per cent or 3 per cent etc for a particular calculation. If the response is outside the range then the student is told 'Your estimate is too large (or too small), try again.' In addition, in such a problem we felt that it was beneficial to give a step-by-step solution to the probelm once the student had finished. This allowed the student to check his or her working against the correct solution, just in case he or she arrived at the correct answer by a number of compensating errors.

Examples of the software used to manage the presentation and data analysis for each question are provided in the complete program listings given in Appendix 1.

In addition to these more standard formats we also experimented with the use of a variety of different video attributes (reverse video, blinking, underline, half-intensity plus combinations of each of these) and also with the graphics mode both of which were features of the Cromemco 3102 video terminal. Examples of these are given below together with the appropriate software.




```
200  REM ••••••••••••••••••••••••••••••••••••
210  REM
220  REM  Checklist for users of CBL-Package . . . . .C.F.A. BRYCE
230  REM
240  REM ••••••••••••••••••••••••••••••••••••
250  REM
255  FOR N=1 To 7
256  @ : Next N
260  Let B$="@ ''''''
```

```
470  GOSUB 1500
480  @"       2.  Switch on the television monitor                    ";
490  GOSUB 1900
500  GOSUB 1800
510  Let B$="d"
520  GOSUB 1500
530  @"       3.  Switch on the Revox microfiche (POWER).             ";
540  GOSUB 1900
550  GOSUB 1800
555  Let B$="d"
560  GOSUB 1500
570  @"       4.  Switch on the audio cassette player (POWER).        ";
580  GOSUB 1900
590  GOSUB 1800
595  Let B$="d"
600  GOSUB 1500
610  @"       5.  Load the microfiche into the reader, using          ";
620  GOSUB 1900
625  Let B$="d"
630  GOSUB 1500
640  @"           the arrows to align the fiche correctly.            ";
650  GOSUB 1900
660  GOSUB 1800
665  Let B$="d"
670  GOSUB 1500
680  @"       6.  Load the audio cassette into the player.            ";
690  GOSUB 1900
700  GOSUB 1800
704  Let B$="d"
705  GOSUB 1500
710  @"       7.  Check to make sure the printer is switched on.      ";
720  GOSUB 1900
730  GOSUB 1800
740  Let B$="H ..........................................................L"
750  GOSUB 1500
800  @CHR$(27);"-";
999  GOTO 10
1000 For N=1 to 120
1010 Next N
1020 Out 116,255
1030 For N=1 to 120
1040 Next N
1050 Return
1500 @Tab (10);
1510 @CHR$(27); "R"; : @B$; : @CHR$(27); "S";
1520 Return
1800 Let B$="d
1810 GOSUB 1500
1820 Return
1900 @CHR$(27); "R"; : @B$; : @CHR$(27); "S";
1910 Return
```

The instruction **@CHR$(27); "R"** switches on the graphics mode (see line 1510) whilst the characters contained within the string **B$** dictate the shape of the graphic symbols. Once printed on the screen, the graphics mode is switched off by the instruction **@CHR$(27); "S"** (see line 1510).

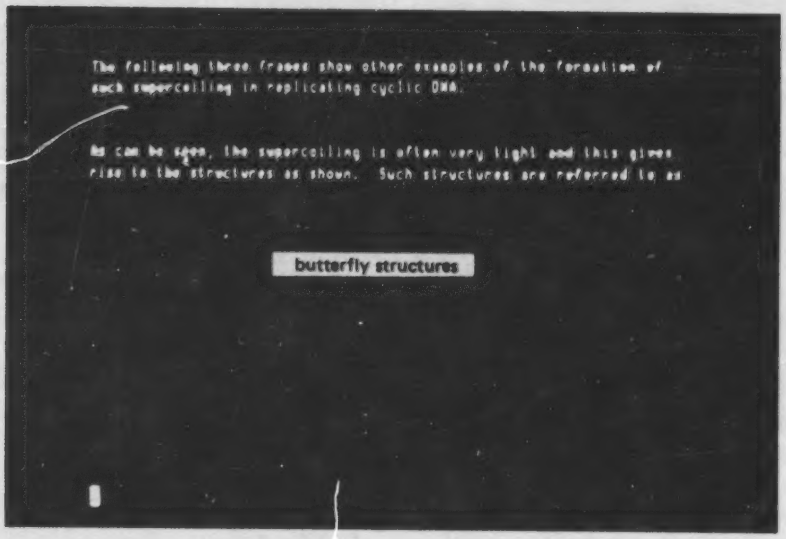
Yes, very well done. The correct answer was indeed supercoiling.
Now have a thought as to why we should get such superhelical twists.

The software used to achieve this effect is as follows:

```
2140  Let T=0
2150  GOSUB 15000
2160  GOSUB 12000
2170  @ : @ : @
2180  @ "Identify the feature that is now apparent in the structure. . ."
2190  @ : @ : @ : GOSUB 13070
2200  @"A  catenation;" : GOSUB 13070
2210  @"B  concatenation;" : GOSUB 13070
2220  @"C  intercalation;" : GOSUB 13070
2230  @"D  supercoiling;" : GOSUB 13070
2240  @"E  ligation;" : GOSUB 13070
2250  @"F  hybridisation."
2260  For J=1 to 6
2270  @ : Next J
2280  Input B$
2290  If B$="D" Then 2590
2300  If B$="A" Then 2530
2310  If B$="C" Then 2470
2320  @ : @ : @
2330  If B$="B" or B$="F" Then 2350
2340  L=8 : GOTO 2360
2350  L=13
2360  @ : @ : @ : @
2370  @"Your answer of";
2380  @CHR$(27); "dP"; : @TAB(15);
2390  If B$="B" Then B$="concatenation"
2400  If B$="E" Then B$="ligation"
2410  If B$= "F" Then B$="hybridisation"
2420  @B$; : @CHR$(27); "d@";
2430  @TAB(15+L); : @"is not the correct response."
2440  @"Try the question one more time"
2450  If T=1 then 2150
2460  GOTO 2740
2470  @ : @ : @
2480  @"Intercalation can certainly lead to this feature. . .but has no"
2490  @"direct consequence in the present consideration. Try the"
2500  @"question once again with this fact in mind."
2510  If T=1 Then 2150
2520  GOTO 2740
2530  @ : @ : @
2540  @"Whilst catenation is a discrete possibility as an interpretation"
2550  @"of this electron micrograph, it is incorrect in the present case."
```

```
2560  @ : @"As a clue, consider the lower half of the molecule. ."
2570  If T=1 Then 2150
2580  GOTO 2740
2590  For J=1 to 6
2600  @ : Next J
2610  @"Yes, very well done. The correct answer was indeed";
2620  @TAB(52);
2640  @CHR$(27); "dC";
2650  @"supercoiling.";
2660  @CHR$(27); "d@";
2700  @ : @ : @
2710  @"Now have a thought as to why we should get such superhelical twists."
2720  For J=1 to 8
2730  @ : Next J
2740  Let N=44 : GOSUB 1400
```

In this example, the word 'supercoiling' in line 2650 appears on screen as half-intensity blinking. Thus the video attribute is changed by the instruction @ CHR$(27); "dC" which puts it into half-intensity blinking whilst @ CHR$(27); "d@" returns the terminal to normal video (see lines 2640 and 2660)

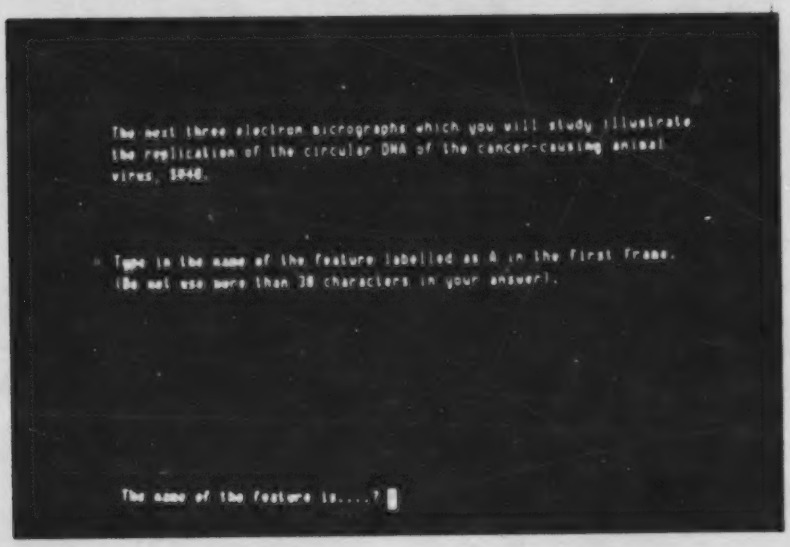

The following three frames show other examples of the formation of
such supercoiling in replicating cyclic DNA.
As can be seen, the supercoiling is often very tight and this gives
rise to the structures as shown. Such structures are referred to as
butterfly structures

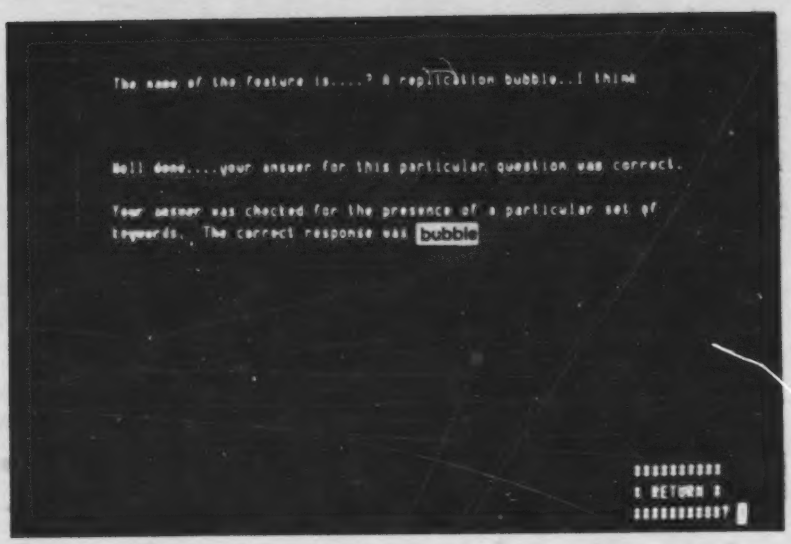
The software used to achieve this effect is as follows:

```
3450  Let N=46 : GOSUB 1400
3460  GOSUB 1500
3470  @ : @
3480  @"The following three frames show other examples of the formation of"
3490  @"such supercoiling in replicating cyclic DNA."
3500  @ : @
3510  Let I=85 : GOSUB 17000
3520  @"As can be seen, the supercoiling is often very tight and this gives"
3530  @"rise to the structures as shown. Such structures are referred to as"
3540  For J=1 to 3
3550  @ : Next J
3560  @TAB(22);
3570  @CHR$(27); "dS";
3580  @"butterfly structures. ";
3590  @CHR$(27); "d@"
3600  For J=1 to 10
3610  @ : Next J
3620  For J=1 to 12000.0
```

```
3630  Next J
3640  J=0
3650  Let I=86 : GOSUB 17000
3660  For J=1 to 12000.0
3670  Next J
3680  J=0
3690  Let I=84 : GOSUB 17000
```

The inverse video attribute is controlled in this case by lines 3570 and 3590.


The next three electron micrographs which you will study illustrate the replication of the circular DNA of the cancer-causing animal virus, SV40.
Type in the name of the feature labelled as A in the first frame. (Do not use more than 30 characters in your answer).
The name of the feature is....?


The name of the feature is....? A replication bubble...I think
Well done....your answer for this particular question was correct.
Your answer was checked for the presence of a particular set of keywords. The correct response was bubble
A RETURN A

In this question we allowed for a free format response. In essence what we were doing is looking for a specific sub-string anywhere within a longer character string B$. This was achieved as follows:

```
1580  Let T=0
1590  GOSUB 15000
1600  GOSUB 12000
1610  @ : @ : @
1620  Let I=81 : GOSUB 17000
1630  @"The next three electron micrographs which you will study illustrate"
1640  @"the replication of the circular DNA of the cancer-causing animal"
1650  @"virus, SV40."
1660  @ : @ : @
1670  @"Type in the name of the feature labelled as A in the first frame."
1680  @"(Do not use more than 30 characters in your answer)."
1690  For J=1 to 9
1700  @ : Next J
1710  @"The name of the feature is. . . .";: Input B$
1720  A=POS(B$, "bubble", 0)
1730  B=POS(B$, "Bubble", 0)
1740  C=POS(B$, "BUBBLE", 0)
1750  D=POS(B$, "eye", 0)
1760  E=POS(B$, "Eye", 0)
1770  F=POS(B$, "EYE", 0)
1780  If A+B+C+D+E+F>-6 THEN 1840
1790  @ : @ : @
1800  @"On checking your answer, the correct keyword could not be found at
      any"
1810  @"point. Try the question one more time."
1820  If T=1 Then 1590
1830  GOTO 1980
1840  @ : @ : @
1850  @"Well done. . . .your answer for this particular question was correct." : @
1860  @"Your answer was checked for the presence of a particular set of"
1870  @"keywords. The correct response was";
1880  @TAB(36);
1890  If A+B+C>-3 Then 1920
1900  B$="eye."
1910  GOTO 1930
1920  B$="bubble."
1930  @CHR$(27); "d@";
1940  @B$;
1950  @CHR$(27); "d@"
1960  For J=1 to 9
1970  @ : Next J
1980  Let N=43 : GOSUB 14000
```

Thus the student responded to the question by typing in his/her free format answer (B$).

The instructions given in lines 1720–1770 check the contents of this string for a number of specific sub-strings. For example, the instruction A=POS(B$, "bubble", Ø) asks the computer to check the character string B$ for the sub-string "bubble" anywhere within its length, starting from the first character (numbered Ø). If such a sub-string is found then the value of A is set to the number of the first character at which the sub-string was found otherwise the value of A is set to −1. Thus the conditional statement given in line 1780 tests to see if any of the specific sub-strings were present in the student answer.

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Interfacing the Audio-Visual Devices

general introduction

Initially the basic rationale for interfacing was essentially a 'black-box' approach in which a logic circuit continuously monitored the information coming from the computer to the terminal. Provided that the information coming down the line was standard information, then the 'black-box' allowed this to proceed uninterrupted to the VDU. If, however, a reserved special character was detected, then the logic circuit was set up to take the next 7-bit code of information and direct this to the audio-visual device. This information never appeared on the VDU screen. In the case of the Revox microfiche system, these 7-bits code for the microfiche grid reference, the first three for the row (A–E or R), the last four for the column (1–12 or 1–6 respectively). When a specific visual is no longer required, a suitably coded signal switches to another visual or, if no visual material is required, switches off the light source on the microfiche monitor. Thus frame E7 would have the 7-bit binary address 1010111 (E ≡ 101, 7 ≡ 0111). Those addresses coded for by the letter R allow the lamp to be switched on or off, the left or right hand only to be switched on or off or the microfiche to be ejected and, as such, are very important features of the system. In addition, by using values of R = 6 and R = 5, it is possible to switch the Revox audiotape recorder on or off respectively, again under software control (see later).

Black-boxes of this type were constructed for operation with the main-frame computer and a variety of stand-alone microcomputers including the Cromemco, the Compucolor, the Commodore PET and the Apple. Later in the project we designed, constructed and implemented interfaces which carried out identical functions but which were designed for use with a parallel output port on the various microcomputers used and these were in general constructed on wire-wrap interface cards which slotted into the expansion slots or S100 bus within the computer. The latter approach was not only more aesthetically pleasing in that a series of additional interface boxes were not apparent to the user but it was also more economic to construct the interfaces in this way. It also allowed the interfaces for more than one audio-visual device to be built on a single card and eliminated the expense of a series of interface boxes. At current costs, the price of two interface cards and the microprocessors etc., required for all audio-visual devices considered in the present study (microfiche, video and audio) is approximately £100.

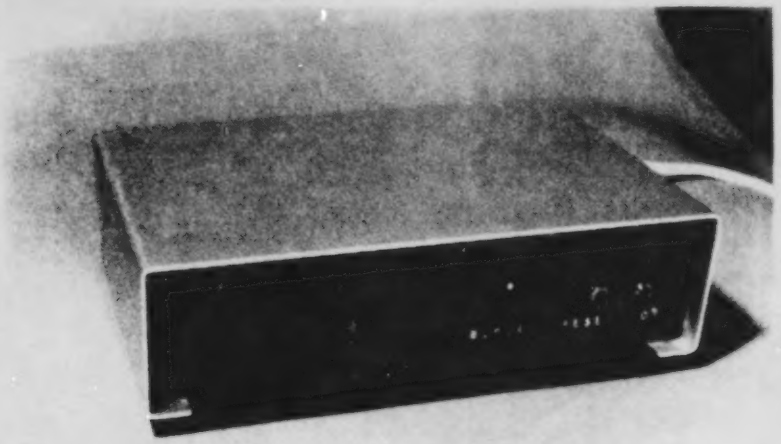
The following sections deal in considerably more detail with the technical aspects of the various units of firmware developed during the present research study and they describe the computer software associated with each of these units.

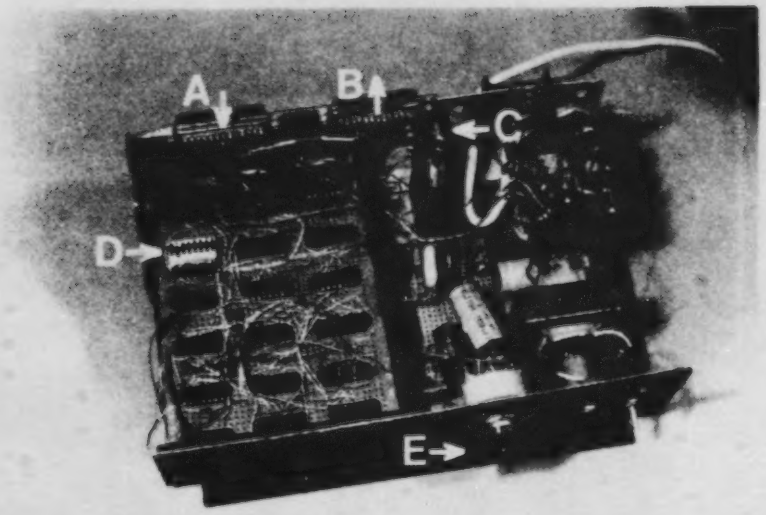
Revox Microfiche/DEC20 Interface

theory of operation

In terms of computer architecture, the approach adopted in interfacing the Revox microfiche unit to the DEC20 main-frame computer was to have an interface box in-line between the central processing unit of the computer and the visual display unit (VDU) of the user. The function of this interface was to monitor the information coming from the computer for a reserved character which would not normally be sent down-line. On identifying such a

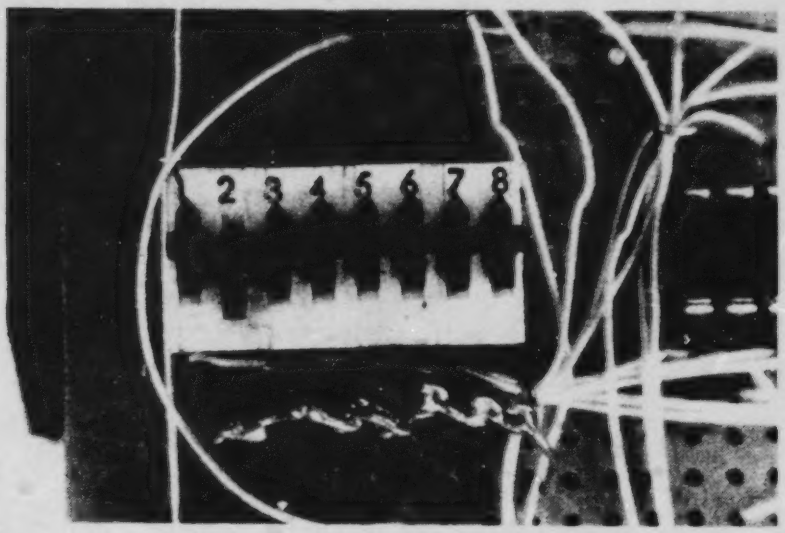
character the circuitry of the interface directed the next 7-bit code of information to the Revox microfiche, this code representing one of the addresses of the microfiche. The figures shown below illustrate the external appearance and internal architecture of such an interface.





Thus, the information sent down-line by the computer to the user enters the interface at the 25-pin D-connector labelled A. If no reserved character is observed, the data passes out of the interface via the D-connector labelled B and proceeds to the user's VDU. If, however, a reserved character is observed, the circuitry takes the next 7-bit code of information, processes this and outputs it via the 7-pin DIN connector labelled C which is connected to the encoder socket of the Revox microfiche system. Switch E allows the user to pre-select the baud rate at which the interface operates, the allowable settings being 110, 300, 1200, 2,400, 4,800 and 9,600 baud.

With regards the reserved character, then this is pre-determined to suit the users own computer system by setting the dual-in-line (DIL) switch shown in the figure below to the binary pattern for the equivalent ASCII code. For the DEC20 this was set for the character ESC, CHR $(27). On the microcomputers used in this study, however, certain of the escape sequence codes were used by the system for specific functions and so for these computers, the reserved character was set to CHR $(2).



programming considerations

The computer software subroutines written to drive the microfiche display for both the main-frame and microcomputer via this interface are listed below.

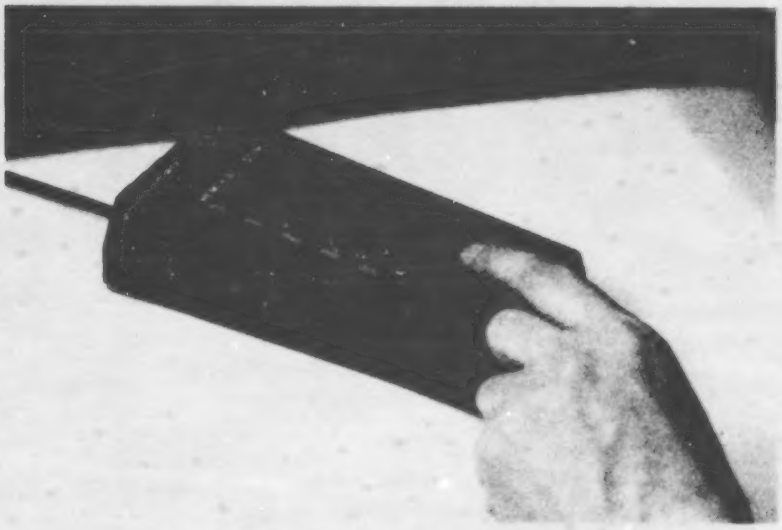
```
97000  REM-SUBROUTINE TO OUTPUT ADDRESS FOR MICROFICHE
           MONITOR (X$,Y)
97010  REM-ERROR FLAG, VALUE RETURNED Z 3 = 0 IF ADDRESS
           VALID
97020  REM-Z 3 = 1 IF ADDRESS INVALID
97030  LET Z 3 = 0
97040  IF X$ = "R" THEN 97130
97050  IF X$ = "A" THEN 97210
97060  IF X$ = "B" THEN 97230
97070  IF X$ = "C" THEN 97250
97080  IF X$ = "D" THEN 97270
97090  IF X$ = "E" THEN 97290
97100  IF X$ = "STOP" THEN 97330
97110  LET Z 3 = 1
97120  RETURN
97130  LET Z 1 = 0
97140  IF Y > 5 THEN 97110
97150  IF Y < 1 THEN 97110
97160  REM-ADDRESS R, 1 REQUIRES OUTPUT OF NULL CHARACTER
97170  REM-NOT POSSIBLE IN BASIC, R, 6 ACHIEVES THE SAME
           EFFECT
97180  IF Y > 1 THEN 97200
97190  LET Y = 6
97200  GOTO 97350
97210  LET Z 1 = 1
97220  GOTO 97300
97230  LET Z 1 = 2
97240  GOTO 97300
97250  LET Z 1 = 3
97260  GOTO 97300
97270  LET Z 1 = 4
97280  GOTO 97300
97290  LET Z 1 = 5
97300  IF Y > 12 THEN 97110
97310  IF Y < 1 THEN 97110
97320  GOTO 97350
97330  LET Z 1 = 6
97340  LET Y = 1

97350  PRINT CHR$(27); CHR$          97350  OUT 1,2 : OUT 1,
       (Z 1.16+Y-1)                         (Z 1.16+Y-1)

97360  RETURN
99999  END
```

Within the body of the program, the instruction to display a particular frame would be given by the instructions:

```
LET X$ = "C"
LET Y = 7
GOSUB 97000
```

Revox Microfiche/Cromemco System 3 Interface

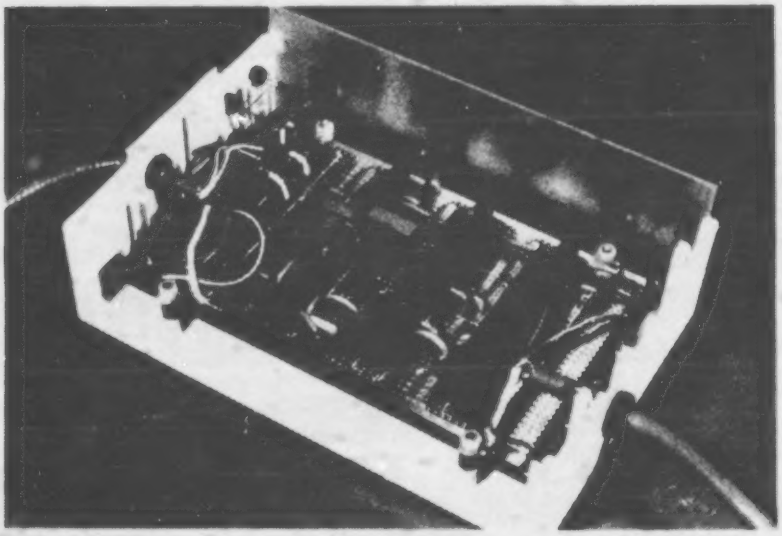
This interface box, which carries out an identical function to that just described for the main-frame computer, was designed to make use of a parallel output port on the microcomputer. As discussed earlier, the rationale for designing such an interface was to by-pass the keyboard of the Revox Audiocard Encoder (shown below).

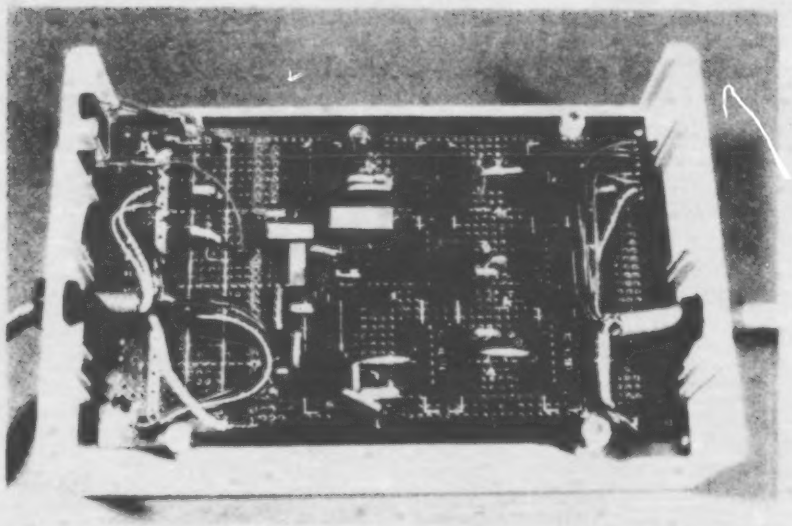


theory of operation

The interface accepts a byte of parallel data from a microprocessor output port and generates serial data compatible with the Revox Audiocard Encoder input so enabling the selection of slide frames under processor control. The circuit mimics that of the Revox Audiocard Keyboard module and so no detailed explanation of its operation will be given. Copies of the circuit diagrams for this interface are given in Appendix 2.

Photographs of the internal architecture of the interface box are given below:





Basically the 'front end' of the unit which interfaced with the keyboard has been removed and the data from the microcomputer is input directly to the parity generator (IC8 on Revox drawing A25) and data multiplexer (IC4). Seven bits (D0 - D6) are used to generate the serial frame code and one bit (D7) for control. The enable latch (IC10) is configured differently. D7 is connected to its 'D' input and a 'Hi' inhibits the serial data to the Revox. A 'Lo' has the converse effect.

The green LED indicates that 5V is present and the red LED indicates that serial data is being sent to the Revox.

using the interfacing

The interface is connected to the Revox Encoder input on the Audio-card Microfiche Unit via the 5 pin DIN plug. The 25 way D-connector is then plugged into the parallel output port of the microcomputer.

The Revox unit is powered, following which the microcomputer can be switched on. The A6 microfiche card is inserted as described by the manufacturers and frame selection can then be executed by use of an appropriate program on the microcomputer.

programming considerations

The following decimal codes select the microfiche frames as shown in the table below:

Decimal Code	Frame Selected
1 – 5	REM2 – REM6
16 – 27	A1 – A12
32 – 43	B1 – B12
48 – 59	C1 – C12
64 – 75	D1 – D12
80 – 91	E1 – E12

Before a new code is output, the interface is disabled for about 100 milliseconds with the old code still present. The following program illustrates this point. Frames A1 to A3 are displayed at 2 second intervals, then the slide is ejected and the sequence repeated indefinately. To start the cycle, any value for a number (L) is entered and this is repeated after each display sequence. The program is written in BASIC and runs at 4MHz with one wait state.

```
10   I=128
20   OUT 100, I
30   J=O
40   INPUT L
50   RESTORE
60   READ I
70   IF I=O GOTO 40
80   GOSUB 140
90   FOR K=1 TO 2400
100  NEXT K
110  GOTO 60
120  DATA 16, 17, 18, 1,0
130  REM Driver Subroutine
140  OUT 100, J + 128
150  FOR K=1 to 250
160  NEXT K
170  OUT 100, I
180  J=1
190  RETURN
200  END
```

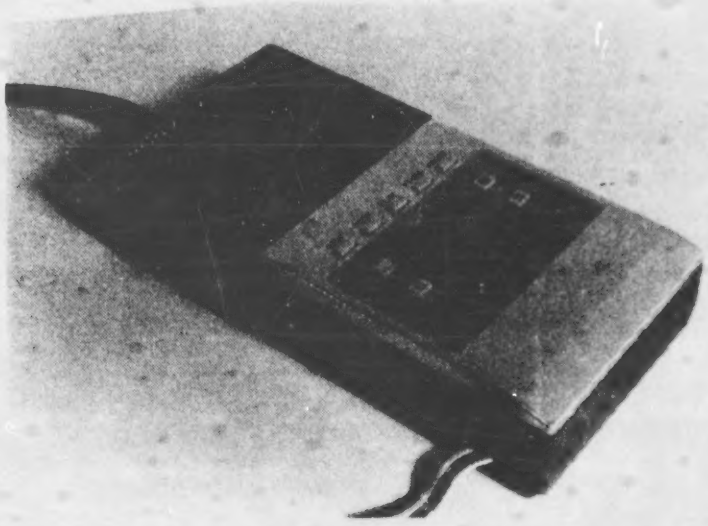
The following remarks apply to the above demonstration program:

Lines 10–30	These instructions make sure that D7 is 'Hi' and the Revox is disabled. In this case, the output port address is 100 but this will differ on other microcomputers.
Line 40	Enter any number to start the sequence
Line 50	Restore the data pointer to the start of the data list
Line 60	Get display code data
Line 70	Check for end. If found, repeat.
Line 80	Call driver subroutine to output to the interface.
Line 90–100	These instructions incorporate a 2 second delay
Line 110	Repeat the sequence
Line 120	Display data, must end with a zero
Line 140	Output the previous code with D7 'Hi'

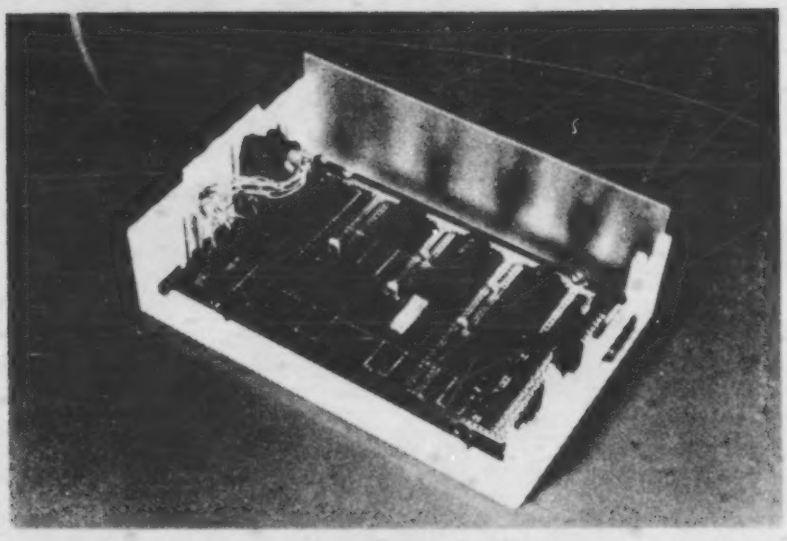
Lines 150–160	100 ms delay while serial data to the Revox is inhibited.
Line 170	Output new code to the interface. D7 is 'Lo'.
Line 180	Set old code to code just output.

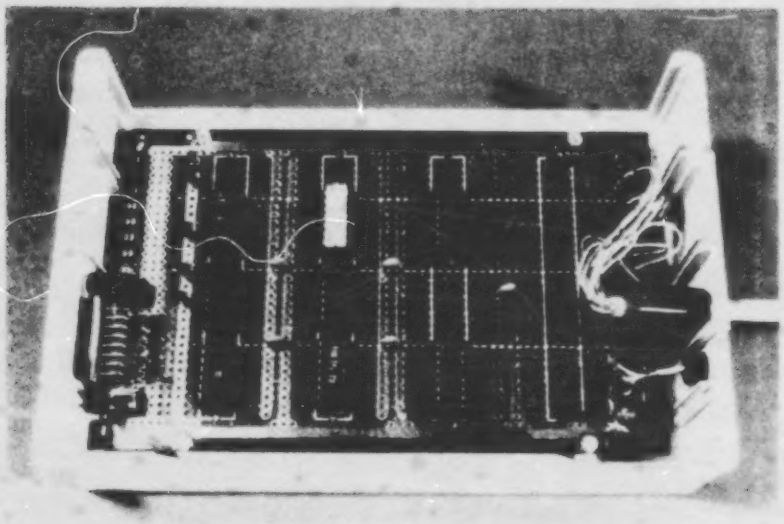
Sony RX-353/Cromemco System 3 Interface

The random–access video recorder has a control box very similar to the microfiche system and it is by means of this microprocessor device that the appropriate segment of video is displayed. The RX-353 Auto Search Control (see photograph below) is designed to quickly locate any desired point on a U-matic videocassette tape, and start playback from that point. With this control system it is possible to memorize the segment data (the number and beginning and end locations) of up to 63 segments. This segment data memorized by the RX-353 can be recorded on the video cassette tape and can, at a later stage, read the segment data recorded on the tape.



In order to control the random-access video system the approach, as was the case with the Revox Audiocard System, was to by-pass the keyboard of the RX-353 Auto Search Control but, in this case, a slightly different method was employed. Instead of having the interface incorporating the circuitry of the control box, we merely built an interface which accessed the switches of the control box and this interface/ control box unit was connected to the microcomputer via a parallel output port. In this way it was still possible to use the control box at any time to either over-ride the computer program or to make full use of all of the special function keys supplied on the control box. The photographs shown below illustrate the internal architecture of the interface box for the random-access video:





theory of operation

The board accepts an 8 bit code on lines D0—D7 in the range 00H to 13H (0 to 19 decimal) and in conjunction with the Y0—Y4 keyboard scanning signals from the Sony RX-353 Auto Search Control module sets one of the X0-X3 outputs to logic low. This is an indication to the RX-353 keyboard scanning I.C. that a key has been pressed and by knowing which one of the X0-X3 lines is low and which one of the Y0-Y4 lines it has activated, it can decide which of the 5x4=20 keys is being pressed. (See RX-353 documentation for the drawing of the keyboard circuitry).

Copies of the circuit diagrams and pin connections for this interface are given in Appendix 2. Please refer to these for the following explanation of the operation of the interface.

C1 is a 2-to-4 decoder which is enabled when $\overline{E1Y}$ is low. This causes one of the 1Y0–1Y3 outputs to go low depending on the code on the A and B inputs. However, if it is disabled by a high on $\overline{E1Y}$, all outputs are high regardless of the code on A and B. Now if either D5, D6 or D7 are high (greater than or equal to 32 decimal) then C1 is disabled and no key push can be simulated.

C3 is a 3-to-8 decoder. This is permanetly enabled and any 3 bit code on the inputs A, B and C causes one of the outputs 3Y0–3Y7 to go low. However, since outputs 3Y5–3Y7 are not connected, only the codes up to XXX100XX (X=not important) have any effect on the rest of the circuitry. Therefore the highest input code to be recognised is XXX10011 (13H or 19 decimal). Assume that the code 0000 1010 (0AH or 10 decimal) has been output from the computer to D7–D0 respectively. C3-13 will be low because the code 010 is present at inputs A, B and C respectively. The rest of C3's outputs will be high. Now assume that the RX-353 keyboard I.C. is starting a scan of lines Y0–Y4. Y0 is brought low but Y1–Y4 remain high. The A2/B2 NOR/INVERTER combination form an OR gate and B2–2,4,6,8,12 form a WIRED–OR connection (i.e. if any of B2–2,4, 6,8,12 go low A3-10 will go low). Since Y0 is low and A2-2 is high, B2-2 will be high. Y1-Y4 are high so B2–4,6,8,12 will be high. Since all the connections to the WIRED-OR are high, A3-10 is high and C1 is disabled. The similar reasoning holds when the RX-353 changes Y0 high and brings Y1 low, C1 remains disabled. However, when Y1 goes high and Y2 is brought low, both inputs to the OR combination are low. B2–6 is then low and assuming that A3–9 is low (i.e. a code less than 32 decimal) C1 is enabled. Since 01 is present on A and B respectively then 1Y2 is low and X2 is low. Now the RX-353 detects that X2 is low when Y2 is low so it can decode this to one of 20 possible keys. In fact the X2/Y2 combination is equivalent to the S/ SEARCH key being pressed.

The following is a list of the hexadecimal and decimal codes on D0-D7 and the effect on the RX-353 unit:

HEX	DECIMAL	X/YCOMBINATION	KEY
00	0	Y4/X0	REW
01	1	Y4/X1	FUNC
02	2	Y4/X2	C/CLEAR
03	3	Y4/X3	M/MEMORY
04	4	Y3/X0	STOP
05	5	Y3/X1	PLAY
06	6	Y3/X2	FFWD
07	7	Y3/X3	PAUSE
08	8	Y2/X0	8/END
09	9	Y2/X1	9/WRITE
0A	10	Y2/X2	S/SEARCH
0B	11	Y2/X3	R/ENTER
0C	12	Y1/X0	4/MODE
0D	13	Y1/X1	5/PCK
0E	14	Y1/X2	6/TIME
0F	15	Y1/X3	7/PRGM
10	16	Y0/X0	0
11	17	Y0/X1	1/TPLAY
12	18	Y0/X2	2/TRUN
13	19	Y0/X3	3/TREC

Y0—Y4 are open collector outputs from the RX-353 so R2-R6 resistors pull them up. X0-X3 are required to be open collector to the RX-353. The A1 gates are open collector outputs but they invert the signal so the B1 inverters counteract this so that X0-X3 follow the 1Y0—2Y3 outputs.

method of connection

The interface box is connected to the system in the sequence as follows:

1. Connect the RX-353 to the V.C.R.
2. Connect the interface to the RX-353 via the 15 way ribbon cable and plug.
3. Connect the interface to the computer via the 25 way plug.
4. Power up computer.
5. Send FFJ or 255 decimal to interface (may be optional).
6. Power up V.C.R.
7. Send codes from computer to simulate key pushes.

The V.C.R. can be powered down and/or the RX-353/interface ribbon cable may be removed or fitted without removing power from the computer but it is not recommended that power is removed from the computer with the RX-353/interface cable connected.

programming considerations

When a valid code is given to the interface it must remain for 100 mS then be removed by writing say 255 decimal to it. This invalid code must remain for 100 mS before a new valid code is given. This has the effect of pushing a key in for 100 mS, removing it and waiting 100 mS before pressing another. So a key push cycle takes 200 mS and the maximum rate is 5 keys/second.

A subroutine for operating the random-access video under software control was written in BASIC and is shown below:

```
98000 OUT 116,255
98020 OUT 116, I
98030 IF I=255 THEN 98100
98040 FOR I=1 TO 100
98050 NEXT I
98060 OUT 116,255
98070 FOR I=1 TO 100
98075 NEXT I
98090 GOTO 98010
98100 FOR N=1 TO 8
98110 @ : NEXT N
98130 @"          *********************************"
98132 @"          *                               *"
98134 @"          *        VIDEO SEGMENT FOLLOWS  *"
98136 @"          *                               *"
98138 @"          *  Type S/RETURN to stop the programme"
98140 @"          *                               *"
98142 @"          *   To restart, depress the RETURN Key"
98144 @"          *                               *"
98146 @"          *********************************"
98147 FOR N=1 TO 8
98148 @ : NEXT N
98150 INPUT A$
98170 IF A$="S" THEN 98180
98171 IF A$="X" THEN 99194
98172 GOTO 99000
98180 OUT 116,7
98190 FOR I=1 TO  100
98195 NEXT I
98200 OUT 116,255
98300 FOR I=1 TO 100
98350 NEXT I
```

```
98400 INPUT A$
98410 GOTO 98170
99000 OUT 116,7
99100 FOR I=1 TO 100
99150 NEXT I
99175 OUT 116,255
99180 FOR I=1 TO 100
99190 NEXT I
99191 GOTO 98150
99194 OUT 116,4
99195 FOR I=1 TO 100
99196 NEXT I
99200 RETURN
99999 END
```

The following remarks apply to the above demonstration program:

Line 98010 — This instruction reads the next DATA statement at that point in the program. For example, if we wanted to find video segment Ø3 and pause at that point then the DATA statement would read

```
DATA 16,19,10,7,4,255
```

Thus the 16 and 19 code for Ø3, the 10 codes for S/SEARCH, the 7 codes for PAUSE (picture still on), the 4 codes for STOP (leaves screen blank) and the 255 is the end message.

Later in the program when we want to PLAY segment Ø3 the software is as follows:

```
DATA  5,255
GOSUB 98000
```

Lines 98040 – 98050 — These instructions incorporate a 100 mS delay.

Line 98170 — This instruction allows the user to "freeze – frame" the video at any point in the playback and as often as he/she requires.

Line 98171 — This instruction allows the user to by-pass a particular video segment if he/she so wishes.

Revox Microfiche/Compucolor II Interface

This interface carries out an identical function to that of the Revox Microfiche/Cromemco System 3 interface. This being the case, only the firmware differences are discussed in this section.

parallel port connections

The connections to be made to the connector for the Compucolor II parallel port are:

Wire	Parallel Port
Brown	Data bit 0
Red	Data bit 1
Orange	Data bit 2
Yellow	Data bit 3
Green	Data bit 4
Blue	Data bit 5
Violet	Data bit 6
Grey	Data bit 7
Black	Ground

Data bit 7 is an enable which must be low for the interface to drive the Revox.

theory of operation

The frame to be displayed is selected by writing a hex byte to the Compucolor II parallel port using the following information:

Frame Letter	1st Hex Digit
R	0
A	1
B	2
C	3
D	4
E	5

Frame Number	2nd Hex Digit
1	0
2	1
3	2
4	3
5	4
6	5
7	6
8	7
9	8
10	9
11	A
12	B

For example, to display frame C10 the code 39H (57 decimal) is written to the parallel port. If at any time a code greater than or equal to 80 H (128 decimal) is written to the interface, it will be disabled as data bit 7 will be high for these codes.

The green LED indicates power on at the interface whilst the red LED indicates that the interface is sending serial data to the Revox. These LED's correspond to the ones on the Revox keyboard encoder.

programming considerations

An example of a BASIC program used to drive the microfiche system from the Compucolor II is given below:

```
100   INPUT A$
200   PRINT I
300   PLOT 14,27,18,3,14,27,13,1
400   POKE 33265, 0
500   I=I + 1
600   IF I<128 THEN 100
700   END
```

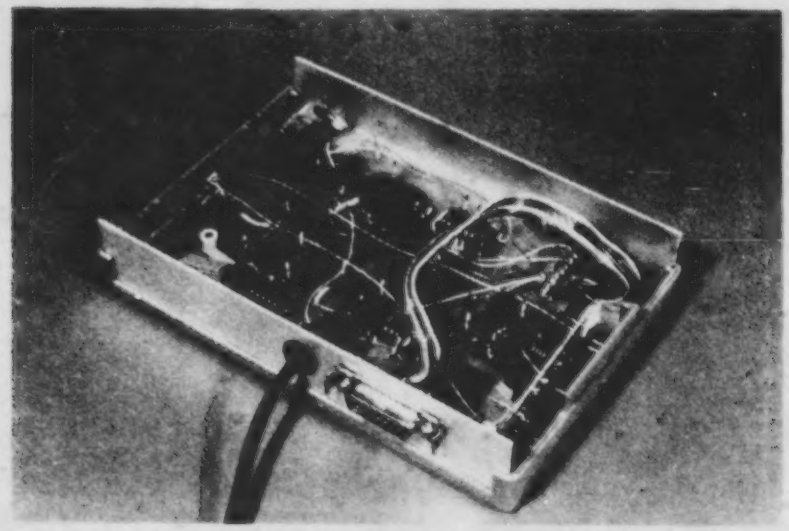
In the PLOT instruction (line 300), the 5-bit codes function as follows:

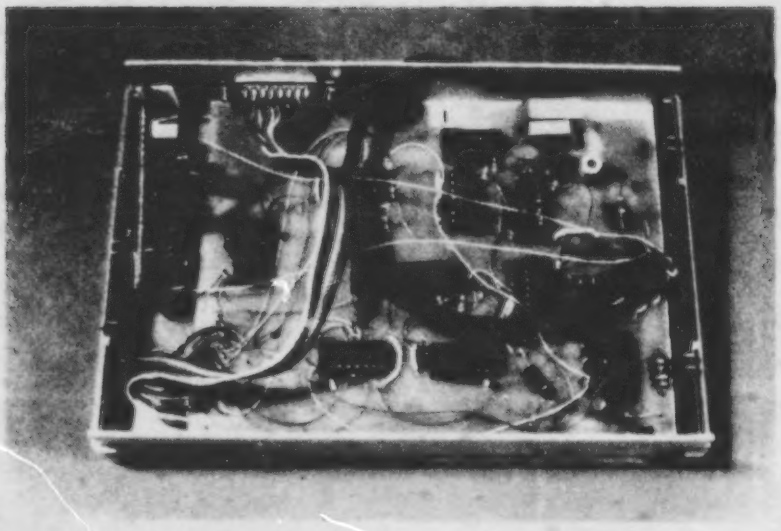
14	sets to ignore all inputs
27	visible cusor mode
18	baud rate selection mode
3	baud rate equivalent to 300
1	sends this value out of the parallel port without any requirement for a handshake.

In the POKE instruction (line 400) the memory location 33265 represents the BASIC output FLAG.

Revox Microfiche/Commodore PET Interface

The interface (see photographs below) used with this microcomputer is identical to that used with the Cromemco System 3, the only difference being in the nature of the software used to drive the microfiche viewer.





programming considerations

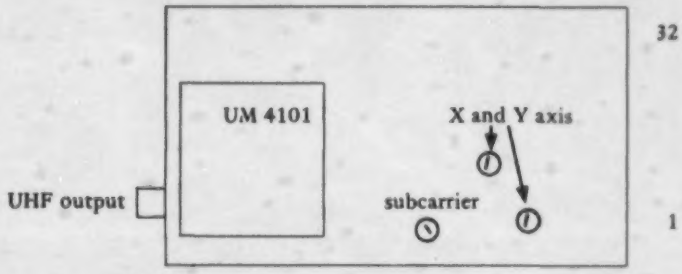
An example of the software for the Revox microfiche/PET microcomputer system is given below:

```
10    X = 59459 : A = 128 : B = 127
20    POKE X.B
30    INPUT "Which frame do you wish?"; N
40    C=B-N : D = A + C
50    POKE X, C : POKE X, D
60    END
```

Acorn Encoder/Cromemco SDI Interface

In the course of this project, we acquired a colour graphics facility for the Cromemco System 3 microcomputer. Initially with this system we were limited to low-resolution and medium-resolution colour graphics because we did not have the two additional 48K pages of dual-port memory. Also, at this time, we did not have an RGB colour monitor but instead were using a colour monitor which received a composite colour video signal so resulting in a black and white signal. This being the case, we investigated potentially inexpensive ways of producing a colour signal from the microcomputer for use on ordinary receivers/monitors. The ACORN Colour Encoder – UHF Modulator (UM 4101) circuit board accepts Red, Green, Blue and synchronisation signals from a video generator and converts them to a composite PAL colour video signal. This is then modulated on to a UHF carrier producing an output suitable for feeding the 75 ohm aerial socket of a domestic television. Colour display of computer output can thus be viewed and this board forms an ideal interface between the Cromemco and a colour TV. The board will also drive a monochrome TV producing black and white picture with the intermediate colours appearing as different levels of grey. The board is designed to operate on 50 fields/second, 625 line TV sytems with a colour sub-carrier at 4.433619 MHz. The circuit board is 100 mm by 122.5 mm in size and it consumes 350 mA from a stabilized 5 volt supply.

top view of encoder board



input signals

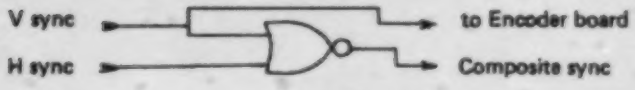
The signal connections are as follows:

Pin 13	+5 volt stabilized supply
Pin 12	Red drive, active high
Pin 11	Green drive, active high
Pin 10	Blue drive, active high
Pin 9	Sound input. Not on the Acorn VDU.
Pin 8	O volt supply, signal common.
Pin 6	Composite sync, active low.
Pin 5	Vertical sync, active high.

The five input signals are all at TTL level and the signal excursions should not exceed the supply voltage. On the Acorn VDU cars Vertical and Horizontal sync are both active high signals, they are fed to one TTL NOR gate which produces the active low Composite sync.

The UHF output is on channel 36 (591.250 MHz). If jagged edges are present on the edges of displayed colour blocks a slight adjustment of the sub-carrier preset is recommended. The X and Y modulation axis adjustments are preset and should not require alteration. The board is available fully assembled and tested at £22.50, excluding VAT.

The PAL encoder will operate without interlace when the relationship between the vertical and horizontal sync signals is the same on all lines as in one or the other of the above field waveforms. In fact the vertical sync signal is only used to trigger a bistable at the start of each field. On the Acorn VDU composite sync is obtained thus:–



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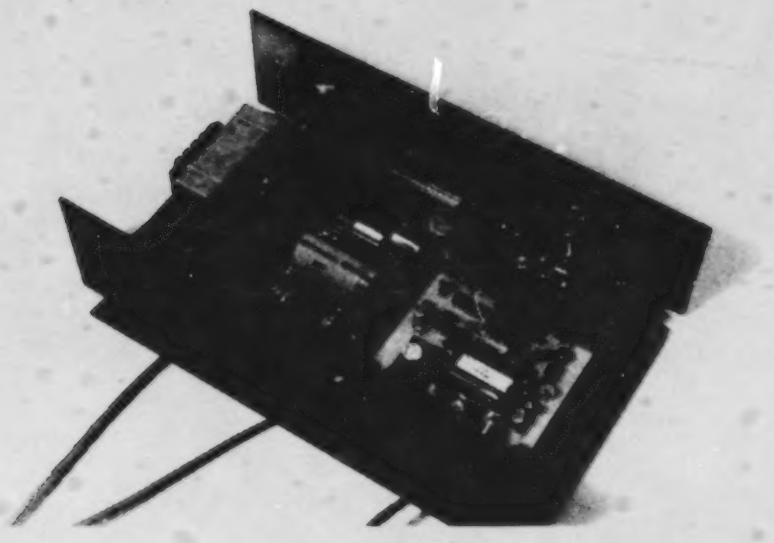
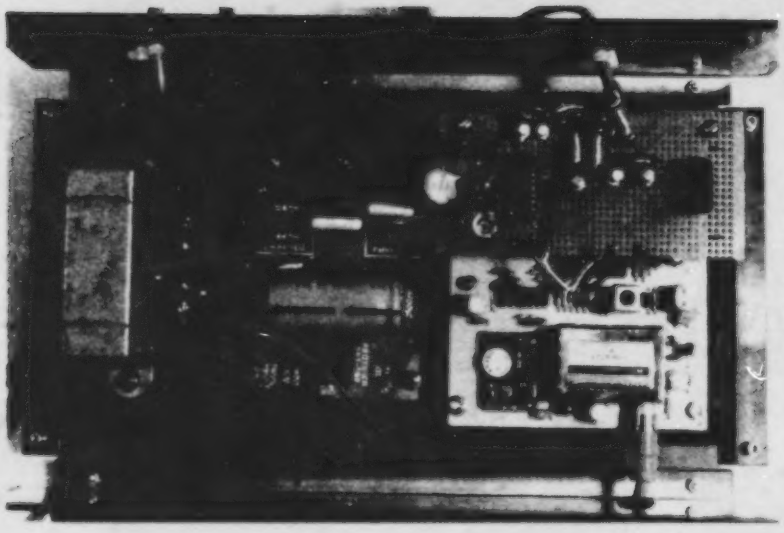
If not available a vertical sync signal is simply obtained using a re-triggerable monostable circuit on composite sync with a time constant just greater than 64 μS. Normally the monostable is constantly set by the horizontal sync pulses but when these stop during the vertical blanking period the monostable drops out producing a vertical sync pulse on its output until the first horizontal sync pulse of the next field appears. When a broadcast TV signal is being used the monostable will need to be preceeded by a circuit which differentiates between normal horizontal sync pulses and the equalising pulses in the vertical blanking period.

The last diagram shows all of the possible states of the colour drive signals and the colours that are produced. Note that there is a generous period of time before the first state and after the last to ensure that all of the states are displayed in full, using the Acorn VDU this period is around 15 μS which produces a border around the information on the screen.

The sound input requires an audio signal of the sort used to drive a small loudspeaker, this is frequency modulated onto a sound sub-carrier by the encoder. Adjusting the coil on the encoder circuit board allows the sub-carrier to be varied between 5.5 and 6.0 MHz.

The internal architecture of the Acorn Encoder/Cromemco SDI interface is shown in the two photographs below and the circuit diagrams for the interface are given in Appendix 2.

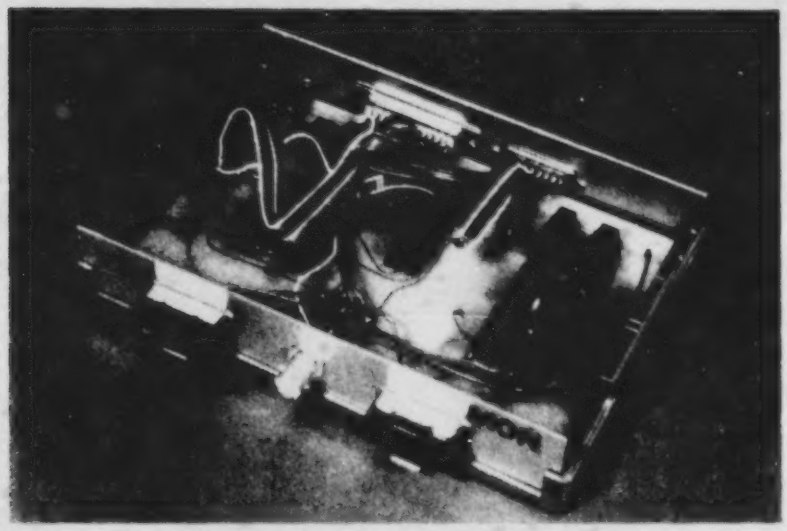


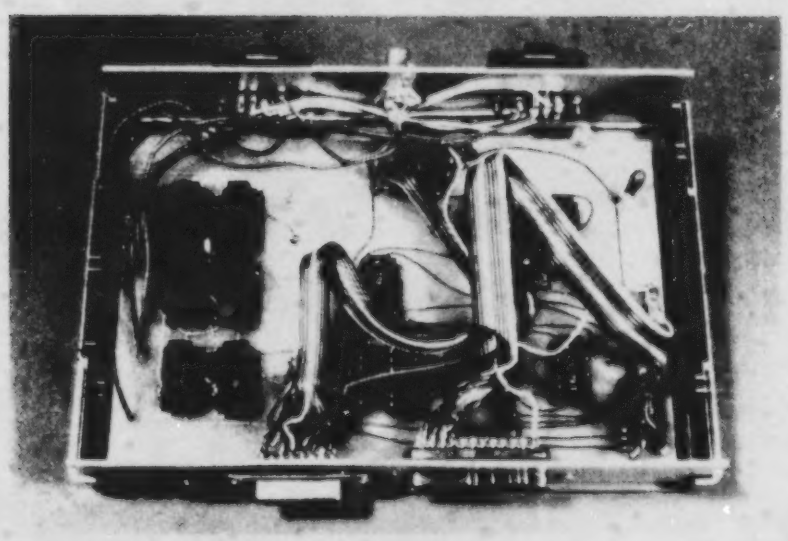


Whilst the results were satisfactory in that we generated a good quality inexpensive colour picture we found that the picture itself was not particularly stable over a long period of time.

Video Switching Interface

With the inclusion of a microfiche viewer and a television monitor in addition to the computer VDU screen, we were conscious of the ergonomic constraints with which a user may be faced. In order to alleviate any such problems, we studied the possibility of combining the TV monitor with the VDU screen, so reducing the system by one screen. Thus, we designed and constructed an interface which allowed the text information coming from the computer to be displayed on the TV monitor as shown below:





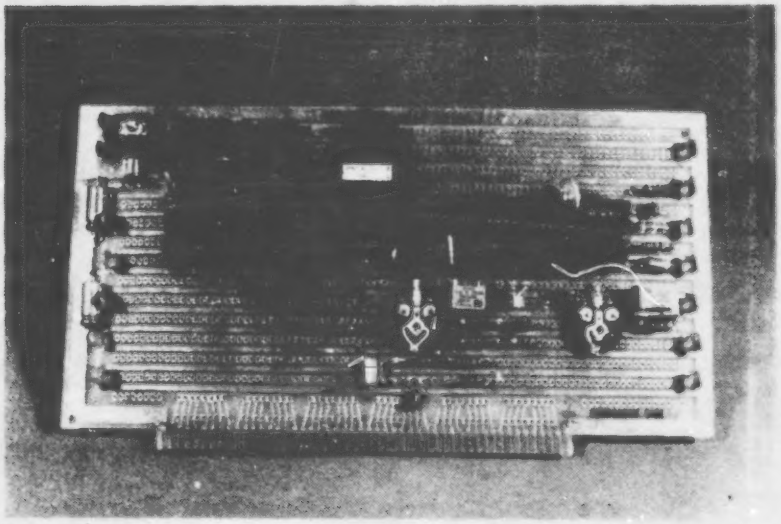
When a video segment was required, an appropriate software instruction switched the flow of information from the VTR to the monitor and allowed the video segment to be displayed. At the end of the video segment, the reverse process was operated. The circuitry for the video switch is provided in Appendix 2.

Whilst the interface carried out this function accurately and correctly we found two disconcerting features from this type of approach. Firstly, the black-level crushing of the video picture had to be set such that the text material from the computer was legible on the screen. The level of crushing that was optimal for the text material was not the same as that for the video segments and so a compromise setting was necessary. The result was that the picture quality was overall diminished.

The second problem arose from the fact that the horizontal settings for the picture had to be re-set in order that no clipping of lines of information occurred. As before this setting was a compromise with that for the optimal video picture. This problem of inter-mixing text material from a computer with video signals from a VTR is one which we are continuing to study in an effort to achieve fully satisfactory results.

Sony RX-353/Revox Microfiche/Revox Audio/ Cromemco System 3 Interface

As the number of interfaces increased as the study progressed, it was felt that it would be of considerable advantage, with respect to the user and with respect to the cost of building interfaces, to combine and construct these on a wire-wrap board which could then be housed internally in the S-100 bus card cage. Such an interface was designed and constructed and is shown in the photograph below:



theory of operation

With regards the Revox units (microfiche and audio), the interface accepts a byte of parallel data from the microprocessor output port and generates serial data compatible with the Revox Audiocard Encoder input so enabling the selection of slide frames or audio segments under processor control. The circuit is virtually identical to that of the Revox Audiocard keyboard module and so no detailed explanation of its operation will be given.

Basically the 'front end' of the unit which interfaced with the keyboard has been removed and the data from the micro is input directly to the parity generator (IC8 on Revox drawing A25) and data multiplexer (IC4). Seven bits (DO-D6) are used to generate the serial frame code and 1 bit (D7) for control. The enable latch (IC10) is configured differently. D7 is connected to its "D" input and a "Hi" inhibits the serial data to the Revox. A "Lo" has the converse effect.

For the video interface, the board accepts an 8 bit code on lines D0-D7 in the range OOH to 13H (0 to 19 decimal) and in conjunction with the Y0-Y4 keyboard scanning signals from the Sony RX-353 Auto Search Control module sets one of the X0-X3 outputs to logic low. This is an indication to the RX-353 keyboard scanning I.C. that a key has been pressed and by knowing which one of the X0-X3 lines is low and which one of the Y0-Y4 lines it has activated, it can decide which of the 5x4=20 keys is being pressed. (See RX-353 documentation for the drawing of the keyboard circuitry).

Refer to the interface drawing given in Appendix 2 for the following explanation of operation.

C6 is a 2-to-4 decoder which is enabled when $\overline{EIY}$ is low. This causes one of the 1Y0-1Y3 outputs to go low depending on the code on the A and B inputs. However, if it is disabled by a high on $\overline{EIY}$, all outputs are high regardless of the code on A and B. Now if either D5, D6 or D7 are high (greater than or equal to 32 decimal) then C6 is disabled and no key push can be simulated).

D6 is a 3-to-8 decoder. This is permanently enabled and any 3 bit code on the inputs A, B and C causes one of the outputs Y0-Y7 to go low. However, since outputs Y5-Y7 are not connected only the codes up to XXX100XX (X = not important) have any effect on the rest of the circuitry. Therefore the highest input code to be recognised is XXX10011 (13H or 19 decimal). Assume that the code 0000 1010 (OAH or 10 decimal) has been output from the computer to D7-D0 respectively. D6-13 will be low because the code 010 is present at inputs A, B and C respectively. The rest of C6's outputs will be high. Now assume that the RX-353 keyboard I.C. is starting a scan of lines Y0-Y4. Y0 is brought low but Y1-Y4 remain high. The D7/C8 NOR/INVERTER combination form an OR gate and C8 - 2, 4, 6, 8, 12 form a WIRED - OR connection (i.e. if any of C8 - 2, 4, 6, 8, 12 go low D8-10 will go low). Since Y0 is low and D7 is high, C8-2 will be high. Y1-Y4 are high so C8 - 4, 6, 8, 12 will be high. Since all the connections to the WIRED-OR are high, D8-10 is high and C6 is disabled. The similar reasoning holds when the RX-353 changes Y0 high and brings Y1 low, C6 remains disabled. However, when Y1 goes high and Y2 is brought low, both inputs to the OR combination are low. C8-6 is then low and assuming that D8-9 is low (i.e. a code less than 32 decimal) C6 is enabled. Since

01 is present on A and B respectively then 1Y2 is low and X2 is low. Now the RX-353 detects that X2 is low when Y2 is low so it can decode this to one of 20 possible keys. In fact the X2/Y2 combination is eqivalent to the S/SEARCH key being pressed.

The following is a list of the hexadecimal and decimal codes on D0-D7 and the effect on the RX-353.

HEX	DECIMAL	X/YCOMBINATION	KEY
00	0	Y4/X0	REW
01	1	Y4/X1	FUNC
02	2	Y4/X2	C/CLEAR
03	3	Y4/X3	M/MEMORY
04	4	Y3/X0	STOP
05	5	Y3/X1	PLAY
06	6	Y3/X2	FFWD
07	7	Y3/X3	PAUSE
08	8	Y2/X0	8/END
09	9	Y2/X1	9/WRITE
0A	10	Y2/X2	S/SEARCH
0B	11	Y2/X3	R/ENTER
0C	12	Y1/X0	4/MODE
0D	13	Y1/X1	5/PCK
0E	14	Y1/X2	6/TIME
0F	15	Y1/X3	7/PRGM
10	16	Y0/X0	0
11	17	Y0/X1	1/TPLAY
12	18	Y0/X2	2/TRUN
13	19	Y0/X3	3/TREC

Y0-Y4 are open collector outputs from the RX-353 so R2-R6 resistors pull them up. X0-X3 are required to be open collector to the RX-353.

Detailed circuit diagrams together with connector tables for this interface card are given in Appendix 2.

programming considerations

The BASIC programs used with this interface for controlling the microfiche viewer and the random-access video are identical to those described earlier for the Revox Microfiche/Cromemco System 3 and the Sony RX-353/Cromemco System 3 interfaces.

With regards the software control of audio segments then this is achieved as follows:

```
1800   OUT 100,6
1810   FOR N=1  TO 8
1820   @ : NEXT N
1840   @"
1850   @"
1860   @"
1870   @"
1880   @"
1890   FOR N=1 TO 7
1900   @ : NEXT N
```

```
**********************
*     AUDIO SEGMENT    *
*  To pause, depress key P  *
*  followed by RETURN key.  *
**********************
```

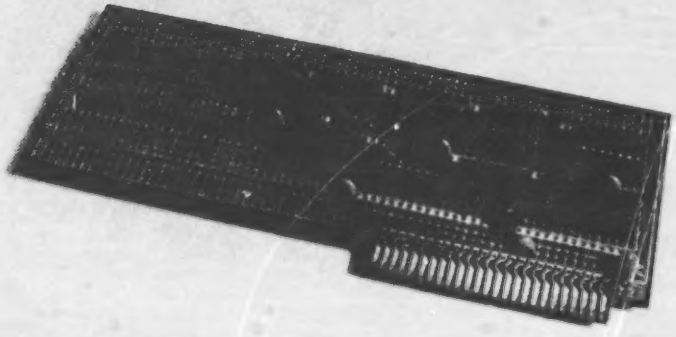
```
15000 REM Subroutine for generating RETURN box
15010 REM
15020 REM ********************************************
15030 REM
15040 @
15050 @TAB(60); : @"**********" : @TAB(60); "* RETURN *" :
      @TAB(60);
15060 @ "**********"; : INPUT B$
15070 IF B$=""THEN 15140
15080 IF B$="O"THEN 15180
15090 IF B$="S"THEN 15200
15100 IF B$="P"THEN 15120
15110 GOTO 15050
15120 OUT 100,5
15130 GOTO 15140
15140 FOR J=1 TO 7
15150 @ : NEXT J : RETURN
```

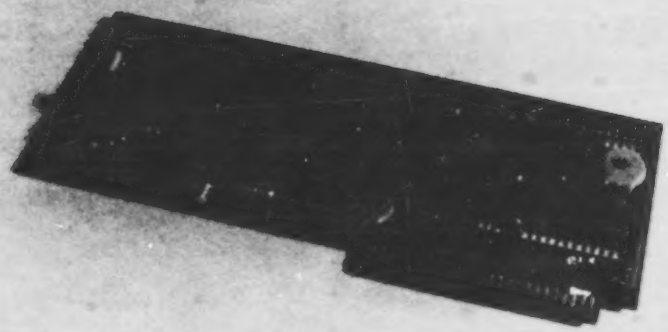
The instruction OUT 100,6 (line 1800) has the effect of switching on the audio tape recorder whilst the instruction OUT 100,5 (line 15120) has the converse effect.

Sony RX-353/Revox Microfiche/Revox Audio/ Apple II Interface

The interface is similar to the Cromemco/Revox interface with the addition of components to provide an 8 bit parallel data latch connected to the apple bus.

These components are A1, B1 and ¼A4.





theory of operation

2 gates of A1 are configured as a latch. On power-up A-2 is "Lo". This causes the latch to SET i.e. A1-12 is "Hi" and the latch is disabled, all output ports are TRI-STATE. This means that the code has no effect on the Revox. After a short while the capacitor on A4-2 charges up, A4-1 goes "Lo" allowing the latch to be RESET by A1-1 when required.

When the board is selected $\overline{\text{DEVSEL}}$ goes "Lo"(A1-3). At the correct moment when the data is valid on the apple bus Q3(A1-4) and 7M(A1-5) go "Lo". This clocks the data into the 8 bit latch (B1) and also RESETS the latch so that A1-12 is "Lo" and B1 output ports are enabled. These output ports stay enabled until power-down.

Apart from these additional integrated circuits the rest of the circuitry is identical to previous Revox/Cromemco interfaces so no explanation will be given.

Sony/Apple

The interface is similar to the Sony/Cromemco interface with the addition of integrated circuits B1, B2 and B3 to provide an 8 bit data latch connected to the apple bus.

On power-up B2-4 is "Lo" and the latch SET's. B2-5 is "Hi" and B1 are output ports TRI-STATE. This has no effect on the Sony. After a short while the capacitor on B2-4 charges up and the SET condition is removed.

When the board is selected $\overline{\text{DEVSEL}}$ goes "Lo" (B3-3). At the correct moment when the data to be written to the Sony board is valid on the Apple bus Q3(B3-4) and 7M(B3-5) go "Lo". This causes the data to be clocked into the 8 bit latch (B1) and also a "Lo" to be clocked onto B2-5 to enable B1 output ports. These output ports stay enabled until power down.

The rest of the circuitry is identical to previous Sony/Cromemco interfaces.

Detailed circuit diagrams together with connector tables for this interface card are given in Appendix 2.

programming considerations

Revox/Apple

The device is written to by executing a POKE X,Y instruction in BASIC. Y is the data to be written and X is a decimal address dependent on the location of the board in the Apple slots. These addresses are:

SLOT	ADDRESS (decimal)	ADDRESS (HEX)
0	49280	ØCØ8ØH
1	49296	ØCØ9ØH
2	49312	ØCØAØH
3	49328	ØCØBØH
4	49344	ØCØCØH
5	49360	ØCØDØH
6	49376	ØCØEØH
7	49392	ØCØFØH

The same procedure for programming is followed as on previous Revox/Cromemco interfaces.

Sony/Apple

The device is written in the same manner as the Revox interface ie POKE address dependent on the location of the board in the apple slots.

```
  5 DIM B$(72)
  7 GOTO 200
 10 OUT 116,255
 20 GOSUB 1000
 30 OUT 116,16
 40 GOSUB 1000
 50 OUT 116,19
 60 GOSUB 1000
 70 OUT 116,10
 80 GOSUB 1000
 82 OUT 116,7
 85 GOSUB 1000
 90 GOTO 2000
200 REM ******************************************************
210 REM
220 REM CHECKLIST FOR USERS OF CBL-PACKAGE.......C.F.A.BRYCE
230 REM
240 REM ******************************************************
250 REM
255  FOR N=1 TO 7
256  @ : NEXT N
260 LET B$="@`````````````````````````````````````````````````````D"
270 GOSUB 1500
280 GOSUB 1800
290 LET B$="d"
300 GOSUB 1500
310 @"    Checklist for users of the multi-media CAL-package   ";
330 LET B$="d"
340 GOSUB 1900
350 LET B$="H`````````````````````````````````````````````````````L"
360 GOSUB 1500
370 @
390 LET B$="@`````````````````````````````````````````````````````D"
395 GOSUB 1500
400 GOSUB 1800
410 LET B$="d"
420 GOSUB 1500
430 @"    1.   Make sure the VTR is switched on and loaded.    ";
440 GOSUB 1900
450 GOSUB 1800
460 LET B$="d"
470 GOSUB 1500
480 @"    2.   Switch on the television monitor.              ";
490 GOSUB 1900
500 GOSUB 1800
510 LET B$="d"
520 GOSUB 1500
530 @"    3.   Switch on the Revox microfiche (POWER).        ";
540 GOSUB 1900
550 GOSUB 1800
555 LET B$="d"
560 GOSUB 1500
570 @"    4.   Switch on the audio cassette player (POWER).   ";
580 GOSUB 1900
590 GOSUB 1800
595 LET B$="d"
600 GOSUB 1500
610 @"    5.   Load the microfiche into the reader, using     ";
620 GOSUB 1900
625 LET B$="d"
630 GOSUB 1500
640 @"         the arrows to align the fiche correctly.       ";
```

```
650 GOSUB 1900
660 GOSUB 1800
665 LET B$="d"
670 GOSUB 1500
680 @"    6.   Load the audio cassette into the player.        ";
690 GOSUB 1900
700 GOSUB 1800
704 LET B$="d"
705 GOSUB 1500
710 @"    7.   Check to make sure the printer is switched on.  ";
720 GOSUB 1900
730 GOSUB 1800
740 LET B$="H``````````````
```

```
 10 DIM O(50)
 20  FOR N=1 TO 10
 30  @ : NEXT N
 40 PRINT"      ************************************************************"
 50 @TAB(6);"*"; : @TAB(64);"*" : @TAB(6);"*";
 60 @"   Extending the Quality of the Learning Experience of    *"
 70 PRINT TAB(6);"*";
 80 @"          Computer-Based Learning and Assessment          *"
 90 @TAB(6);"*"; : @TAB(64);"*" : @TAB(6);"*";
100 @"        Charles F.A. Bryce & Alistair M. Stewart          *"
110 @TAB(6);"*"; : @TAB(64);"*"
120 PRINT"      ************************************************************"
130 @ : @ : @
150 GOSUB 80000
160 GOSUB 55000
170 PRINT"This EM illustrates an osmotically ruptured bacteriophage."
180 LET I=16 : GOSUB 97000
190 PRINT"What is the chemical composition of the material extruded ?"
200 @ : @ : GOSUB 70000
210 @"A    histones ;" : GOSUB 70000
220 @"B    denatured protein ;" : GOSUB 70000
230 @"C    DNA ;" : GOSUB 70000
240 @"D    RNA ;" : GOSUB 70000
250 @"E    membrane ;" : GOSUB 70000
260 @"F    carbohydrate ;" : GOSUB 70000
270 @"G    tail fibres ." :  FOR J=1 TO 5
280  @ : NEXT J : INPUT B$ : IF B$="C"THEN 310
290 @ : @ : @"This is not the correct answer......try again." : IF T=1 THEN 150
300 GOTO 360
310 @ : @
320 PRINT"Well done.  By looking at the amount of DNA that somehow has to be"
330 PRINT"packaged into the bacteriophage will give you some idea of"
340 PRINT"the problem."
350 LET N=1 : GOSUB 75000
360  FOR J=1 TO 6
370  @ : NEXT J : LET T=0
380 GOSUB 80000
390 GOSUB 55000
400 PRINT"Looking at the electron micrograph, what shape do you think the"
410 PRINT"bacteriophage has ?"
420 @ : GOSUB 70000
430 @"A    linear ;" : GOSUB 70000
440 @"B    open cyclic ;" : GOSUB 70000
450 @"C    closed cyclic ;" : GOSUB 70000
460 @"D    Hershey circle ;" : GOSUB 70000
470 @"E    catenane ;" : GOSUB 70000
480 @"F    concatenane ;" : GOSUB 70000
490 @"G    supercoiled ;" :  FOR J=1 TO 7
500  @ : NEXT J : INPUT B$ : @ : @ : IF B$="A"THEN 540
510 PRINT"Wrong answer ..... look more carefully, then try again."
520 IF T=1 THEN 380
530 GOTO 580
540 @ : @
550 PRINT"Well done.....the two ends can be seen clearly at 4 o'clock and 8 "
560 PRINT"o'clock respectively."
570 LET N=2 : GOSUB 75000
580 GOSUB 80000
590 PRINT"The following EM shows another illustration of the same thing...."
600 PRINT"this time the bacterium is Haemophilus influenzae."
610 LET I=17 : GOSUB 97000
620 @ : @
630 PRINT"Here the DNA is a single molecule of length 832 micrometres !!"
```

```
640  FOR J=1 TO 8
650  @ : NEXT J : LET T=0
660 GOSUB 80000
670 GOSUB 55000
680 LET J=0
690 PRINT"In the space-filling model of DNA as shown, what feature is"
700 PRINT"labelled as [A] ?"
710 LET I=18 : GOSUB 97000
720 @ : @ : GOSUB 70000
730 @"A     deep groove ;" : GOSUB 70000
740 @"B     narrow groove ;" : GOSUB 70000
750 @"C     phosphodiester backbone ;" : GOSUB 70000
760 @"D     phosphate groups ;" : GOSUB 70000
770 @"E     nucleotide bases ." :  FOR J=1 TO 7
780  @ : NEXT J : INPUT B$ : IF B$="A"THEN 830
790 @ : @
800 PRINT"No, this is not the correct answer...try one more time."
810 IF T=1 THEN 660
820 GOTO 880
830 @ : @                                                                    very"
840 PRINT"Yes, well done.  The distinction between deep and narrow grooves is
850 @"important when we come to consider enzyme-binding to DNA and also the"
860 PRINT"binding of certain antibiotics."
870 LET N=3 : GOSUB 75000
880 LET T=0
890 GOSUB 80000
900 GOSUB 55000
910 PRINT"From the same frame, can you deduce which crystallographic form of"
920 PRINT"DNA this represents ?"
930 @ : @ : GOSUB 70000
940 @"A     A-form ;" : GOSUB 70000
950 @"B     B-form ;" : GOSUB 70000
960 @"C     C-form ." :  FOR J=1 TO 9
970  @ : NEXT J : INPUT B$ : IF B$="B"THEN 1040
980 @ : @
990 PRINT"No, wrong answer...try again, this time look to see if the base pairs"
1000 PRINT"are at right-angles to the backbone.  This should help you to dis-"
1010 PRINT"tinguish between the different possible forms."
1020 IF T=1 THEN 890
1030 GOTO 1080
1040 @ : @
1050 PRINT"Well done...The clue here was too see whether or not the base pairs"
1060 PRINT"were at right angles to the length of the double helix."
1070 LET N=4 : GOSUB 75000
1080 LET T=0
1090 GOSUB 80000
1100 GOSUB 55000
1110 PRINT"Use the scale provided in the frame shown to estimate the dimensions"
1120 PRINT"of the deep groove."
1130 LET I=19 : GOSUB 97000
1140  FOR N=1 TO 4
1150  @ : NEXT N
1160 PRINT"What is your estimate (in Angstroms).....";
1170  FOR J=1 TO 10
1180  @ : NEXT J : INPUT N : IF N<17.6 THEN 1280
1190 IF N>1.2*22 THEN 1240
1200 @ : @
1210 PRINT"Well estimated...the literature value is quoted to be 22 Angstroms."
1220 LET N=5 : GOSUB 75000
1230 GOTO 1310
1240 @ : @
1250 PRINT"Your estimate is too high.....try again."
```

```
260 IF T=1 THEN 1090
270 GOTO 1310
280 @ : @
290 PRINT"Your estimate is too low......try again."
300 IF T=1 THEN 1090
310 LET T=0
320 GOSUB 80000
330 GOSUB 55000
340 PRINT"Using the same frame, now estimate the dimension of the narrow groove."
350  FOR N=1 TO 4
360  @ : NEXT N
370 PRINT"What is your estimate (in Angstroms)......";
380  FOR J=1 TO 11
390  @ : NEXT J : INPUT N : IF N<9.6 THEN 1490
400 IF N>1.2*12 THEN 1450
410 @ : @
420 PRINT"Well estimated...the literature value is quoted to be 12 Angstroms."
430 LET N=6 : GOSUB 75000
440 GOTO 1520
450 @ : @
460 PRINT"Your estimate is too high.....try again."
470 IF T=1 THEN 1320
480 GOTO 1520
490 @ : @
500 PRINT"Your estimate is too low......try again."
510 IF T=1 THEN 1320
520 LET T=0
530 GOSUB 80000
540 GOSUB 55000
550 PRINT
560 PRINT"The figure shown illustrates an X-ray diffraction pattern of a DNA"
570 PRINT"fibre.  What feature is typical of the scattering pattern of helices ?"
580 LET I=20 : GOSUB 97000
590 @ : @ : GOSUB 70000
600 @"A    the concentric circles ;" : GOSUB 70000
610 @"B    the central hole ;" : GOSUB 70000
620 @"C    the furthermost spots ;" : GOSUB 70000
630 @"D    the central X-shaped pattern ;" : GOSUB 70000
640 @"E    the areas with no spots ." :  FOR J=1 TO 6
650  @ : NEXT J : INPUT B$
660 IF B$="D"THEN 1930
670 IF B$="A"THEN 1830
680 IF B$="B"THEN 1750
690 IF B$="C"THEN 1870
700 @ : @
710 PRINT"No sorry, this is incorrect...areas with no spots do not really tell"
720 PRINT"us too much...try the question again."
730 IF T=1 THEN 1530
740 GOTO 1980
750 @ : @
760 PRINT"No sorry, this is incorrect...this central hole is in fact caused by"
770 PRINT"those X-rays which are not diffracted at all...this represents a high"
780 PRINT"percentage of the original X-ray beam and so 'burns' a hole in the"
790 PRINT"photographic paper used to detect the diffraction pattern. Try the"
800 PRINT"question once again."
810 IF T=1 THEN 1530
820 GOTO 1980
830 @ : @
840 PRINT"No sorry, try the question again."
850 IF T=1 THEN 1530
860 GOTO 1980
870 @ : @
```

```
880 PRINT"No sorry, in a later question you will see that these represent high"
890 PRINT"resolution spots and therefore only provide us with more detailed fine
900 PRINT"structure.  Try the question once again."
910 IF T=1 THEN 1530
920 GOTO 1980
930 @ : @
940 PRINT"Well done...the X-shaped pattern is not too clear in this particular"
950 PRINT"diffraction pattern.  The reason for this in this case is because"
960 PRINT"the fibres used were not very highly ordered."
970 LET N=7 : GOSUB 75000
980 LET T=0
990 GOSUB 80000
000 GOSUB 55000
010 @ : @
020 PRINT"Using the same frame, identify those spots which provide data for low"
030 PRINT"resolution studies (4-6 Angstroms)."
040 @ : @ : GOSUB 70000
050 @"A    the innermost spots ;" : GOSUB 70000
060 @"B    the outermost spots ;" : GOSUB 70000
070 @"C    cannot achieve such resolution using X-rays ;" : GOSUB 70000
080 @"D    require isomorphous replacement ." :  FOR J=1 TO 6
090  @ : NEXT J : INPUT B$
110 IF B$="A"THEN 2320
120 IF B$="B"THEN 2250
130 IF B$="C"THEN 2180
140 @ : @
150 PRINT"No, this has really no relevence to the question that was asked."
160 IF T=1 THEN 1990
170 GOTO 2390
180 @ : @
190 PRINT"Oh yes you can !!  In theory, the resolving power of X-rays is"
200 PRINT"sufficient to identify a single atom.  In practice, however, this"
210 PRINT"is never achieved..the best resolution obtained at the present time"
220 PRINT"is about 2 Angstroms."
230 IF T=1 THEN 1990
240 GOTO 2390
250 @ : @
260 PRINT"No, as it turns out, these spots represent high resolution spots..."
270 PRINT"say about 2 Angstroms.  The consequence of this is that these spots"
280 PRINT"tend to be very diffuse and fuzzy and so make accurate results"
290 PRINT"difficult to achieve."
300 IF T=1 THEN 1990
310 GOTO 2390
320 @ : @
330 PRINT"Absolutely correct.  In general these tend to be sharp, well-defined"
340 PRINT"spots so making accurate determinations possible."
350 LET N=8 : GOSUB 75000
360 LET I=4 : GOSUB 97000
390 DATA 7,5,255
400 GOSUB 98000
410 LET T=0
420 GOSUB 80000
430 GOSUB 55000
440 PRINT"Shown here are a space-filling model and line drawing of a DNA"
450 PRINT"double helix.  Use the information in the frame to calculate the"
460 PRINT"number of base-pairs per crystallographic repeat of 34 Angstroms."
470 LET I=21 : GOSUB 97000
480  FOR N=1 TO 4
490  @ : NEXT N
500 LET I=5 : GOSUB 97000
510 PRINT"What is your estimate for the number of base-pairs....";
520  FOR J=1 TO 9
```

```
2530  @ : NEXT J : INPUT M : IF M=10 THEN 2590
2540 @ : @
2550 PRINT"Your estimate is incorrect...look more carefully and try once again !"
2560  FOR N=1 TO 3
2570  @ : NEXT N : IF T=1 THEN 2420
2580 GOTO 2630
2590 @ : @
2600 PRINT"There are indeed 10 base-pairs per crystallographic repeat of 34"
2610 PRINT"Angstroms (i.e. one complete turn of the helix)."
2620 LET N=9 : GOSUB 75000
2630 LET T=0
2640 GOSUB 80000
2650 GOSUB 55000
2660 PRINT"Given that the molecular weight of an 'average' base-pair is about"
2670 PRINT"710, calculate how long an extended linear DNA molecule of m.wt."
2680 PRINT"10 E9 would be in mm (1 Angstrom = 10 E-8 cm)."
2690  FOR N=1 TO 3
2700  @ : NEXT N
2710 PRINT"Your estimate of the length (in mm) is....";
2720  FOR J=1 TO 10
2730  @ : NEXT J : INPUT N
2740 IF N<0.9*47.887 THEN 2980
2750 IF N>1.1*47.887 THEN 3040
2760 @ : @
2770 PRINT"Very well done...just as a check on your working, compare with the"
2780 PRINT"following rationale :"
2790 PRINT
2800 PRINT TAB(10);
2810 PRINT"- 10 base-pairs occupy 34 Angstroms"
2820 PRINT TAB(10);
2830 PRINT"- m.wt. of 10 such base-pairs = 710 x 10 = 7100"
2840 PRINT"          - therefore, a molecule of molecular weight of 7100 has a"
2850 PRINT"            length of 34 x 10E-8 cm"
2860 PRINT"          - therefore, a molecule of m.wt. of 10 E9 has a"
2870 PRINT"            length of :"
2880 PRINT TAB(24);
2890 PRINT"( 10 E9  x  34  x  10 E-8 ) / 7100"
2900 PRINT TAB(24);
2910 PRINT"= 0.047887 cm"
2920 PRINT TAB(24);
2930 PRINT"= 47.9 mm"
2940 PRINT TAB(24);
2950 PRINT"  ------"
2960 LET N=10 : GOSUB 75000
2970 GOTO 3090
2980 @ : @
2990 PRINT"Your estimate for the length of the DNA is too small.  Go through the"
3000 PRINT"calculation once again, paying particular attention to the various"
3010 @"units."
3020 IF T=1 THEN 2640
3030 GOTO 3090
3040 @ : @
3050 PRINT"Your estimate for the length of the DNA is too high.  Go through the"
3060 PRINT"calculation once again, paying particular attention to the various"
3070 @"units."
3080 IF T=1 THEN 2640
3090 GOSUB 80000
3100 PRINT"So far in this programme, we've really only dealt with the double "
3110 PRINT"stranded form of DNA.  It is worthwhile remembering, however, that"
3120 PRINT"we do find other forms in nature and it is this aspect of DNA"
3130 PRINT"structure which we shall consider in detail now."
3140 PRINT
```

```
150 PRINT"To start with, consider the electron micrograph as shown."
160 LET I=22 : GOSUB 97000
170  FOR J=1 TO 8
180  @ : NEXT J
190 GOSUB 80000
200 PRINT"In this frame, we can see an extended DNA fibre.  To the right of the"
210 PRINT"arrow, the molecule consists of a double-stranded helix whilst to the"
220 PRINT"left of the arrow, the molecule consists of only a single poly-"
230 PRINT"nucleotide strand, one of the complementary strands having been re-"
240 PRINT"moved before the preparation was shadowed."
250 PRINT
260 PRINT"Look carefully.....can you see the difference in width ?"
270  FOR N=1 TO 7
280  @ : NEXT N : LET T=0
290 GOSUB 80000
300 GOSUB 55000
310 @"The electron micrograph shown on the cover of the instruction book "
320 @"represents DNA prepared by the Kleinschmidt method.  [A] is a molecule"
330 @"of double-stranded DNA whilst [B] is single-stranded.  As you can see"
340 @"single-stranded DNA is distiguished on EM from double-stranded DNA by"
350 @"its relative thinness and kinkiness."
360 @"Which physical property of DNA can be explained in just these terms ?"
370 PRINT
380 GOSUB 70000
390 PRINT"A    boiling point;"
400 GOSUB 70000
410 PRINT"B    chirality;"
420 GOSUB 70000
430 PRINT"C    viscosity;"
440  FOR J=1 TO 7
450  @ : NEXT J : INPUT B$
460 IF B$="C"THEN 3540
470 PRINT
480 PRINT"No sorry....";
490 PRINT TAB(12);
500 PRINT B$;
510 PRINT TAB(14);"is not the correct response to the question."
520 IF T=1 THEN 3290
530 GOTO 3580
540 @ : @
550 PRINT"Yes, well done.  Because double-stranded DNA is more rigid a molecule"
560 PRINT"compared with single-stranded DNA, it has a higher viscosity."
570 LET N=11 : GOSUB 75000
580 LET T=0
590 GOSUB 80000
600 GOSUB 55000
610 PRINT"Here we see a hypothetical model of the type of base-pairing that"
620 PRINT"might occur in single-stranded DNA.  Compared with a similar sized"
630 PRINT"double-stranded DNA, which of the following might be expected ?"
640 LET I=24 : GOSUB 97000
650 @ : @ : GOSUB 70000
660 PRINT"A    single-stranded has a higher viscosity"
670 GOSUB 70000
680 PRINT"     than double-stranded ;"
690 GOSUB 70000
700 PRINT"B    single-stranded shows a sharper transition"
710 GOSUB 70000
720 PRINT"     in hyperchromicity on heating above Tm ;"
730 GOSUB 70000
740 PRINT"C    single-stranded does not exhibit a cooperative"
750 GOSUB 70000
760 PRINT"     transition on melting."
```

```
770  FOR J=1 TO 6
780  @ : NEXT J : INPUT B$ : IF B$="C"THEN 3830
790 PRINT"No, your choice is incorrect!.....think about it a little longer"
800 PRINT"then try once again."
810 IF T=1 THEN 3590
820 GOTO 3880
830 PRINT"Yes, well done.  The simplest way to rationalise this is to consider"
840 PRINT"different regions undergoing local helix -> coil transistions "
850 PRINT"independently of the structure as a whole."
860 LET N=12 : GOSUB 75000
870 GOSUB 80000
880 PRINT"Thus far in the programme, we have really only considered DNA to be a"
890 PRINT"linear, double-stranded structure.  Indeed, as you will probably"
900 PRINT"know from the lecture programme, not all naturally-occuring DNA is"
910 PRINT"present in this form.  In vivo we can have double-stranded or single-"
920 PRINT"stranded DNA - we can have linear or cyclic DNA and, in addition, a"
930 PRINT"wide variety of permutations of these forms.  Some of the different"
940 PRINT"forms of DNA are shown in the frame.  Consider these for a few minutes"
950 PRINT"then attempt the related questions that follow."
960  FOR J=1 TO 7
970  @ : NEXT J : LET I=25 : GOSUB 97000
980 LET T=0
990 GOSUB 80000
000 GOSUB 55000
010 PRINT"Shown here are some tertiary structures of DNA from Drosophila"
020 PRINT"(the molecule indicated by the arrow is a marker DNA from PM2 virus)."
030 PRINT
040 PRINT"What form does molecule A adopt ?"
050 LET I=26 : GOSUB 97000
060 @ : @ : GOSUB 70000
070 PRINT"A    open cyclic;"
080 GOSUB 70000
090 PRINT"B    closed cyclic;"
100 GOSUB 70000
110 PRINT"C    Hershey circle;"
120 GOSUB 70000
130 PRINT"D    catenate;"
140 GOSUB 70000
150 PRINT"E    concatenate;"
160 GOSUB 70000
170 PRINT"F    supercoiled;"
180  FOR J=1 TO 7
190  @ : NEXT J : INPUT B$
200 IF B$="A"THEN 4390
210 IF B$="B"THEN 4390
220 IF B$="C"THEN 4390
230 IF B$="D"THEN 4290
240 IF B$="E"THEN 4340
250 PRINT"No, supercoiled DNA has a very distinctive visual appearance.   Look"
260 PRINT"more carefully, then try again."
270 IF T=1 THEN 3990
280 GOTO 3990
290 PRINT"No, catenated DNA is characterized by having two or more circular "
300 PRINT"DNA's interlinked as links in a chain (catena: Gk for chain).  Look"
310 PRINT"more carefully, then try again."
320 IF T=1 THEN 3990
330 GOTO 3990
340 PRINT"No, concatenated DNA is a very long linear structure (see later, the"
350 PRINT"rolling circle model of DNA replication).  Look more carefully, then"
360 PRINT"try again."
370 IF T=1 THEN 3990
380 GOTO 3990
```

```
390 @"Yes,well done.....your choice of";
400 @TAB(34); : @B$; : @TAB(36); : @"is perfectly correct."
410 PRINT
420 PRINT"It is worthwhile noting, however, that an answer of ";
430 IF B$="A"THEN 4470
440 IF B$="B"THEN 4490
450 LET S$="A and B"
460 GOTO 4500
470 LET S$="B and C"
480 GOTO 4500
490 LET S$="A and C"
500 @TAB(52);
510 PRINT S$;
520 PRINT TAB(60);
530 PRINT"would have"
540 PRINT"been equally acceptable.  Consider the structure again and see if you"
550 PRINT"agree with this statement."
560 LET N=13 : GOSUB 75000
570 LET T=0
580 GOSUB 80000
590 GOSUB 55000
600 PRINT"Using the same frame, identify the tertiary structure exhibited by the
610 PRINT"DNA molecule labelled B."
620 @ : @ : GOSUB 70000
630 PRINT"A    open cyclic;"
640 GOSUB 70000
650 PRINT"B    closed cyclic;"
660 GOSUB 70000
670 PRINT"C    Hershey circle;"
680 GOSUB 70000
690 PRINT"D    catenated;"
700 GOSUB 70000
710 PRINT"E    concatenated;"
720 GOSUB 70000
730 PRINT"F    supercoiled."
740  FOR J=1 TO 7
750  @ : NEXT J : INPUT B$
760 IF B$="F"THEN 4850
770 PRINT"No, sorry.....answer ";
780 PRINT TAB(21);
790 PRINT B$;
800 PRINT TAB(23);
810 PRINT"is not the correct answer in this case.  Look"
820 PRINT"more carefully at the EM.....It really isn't all that difficult !!"
830 IF T=1 THEN 4580
840 GOTO 4890
850 PRINT"Well done, although this one was fairly easily identified.  Super-"
860 PRINT"coiled DNA always has the appearance of KNOTTED STRING owing to the"
870 PRINT"extra superhelical twists that have been incorporated into the"
880 PRINT"structure just prior to covalently closing the ring."
890 LET N=14 : GOSUB 75000
900 LET T=0
910 GOSUB 80000
920 GOSUB 55000
930 PRINT"The question which follows is still related to the same frame."
940 PRINT
950 PRINT"Given that the contour length of the viral DNA is 3000 Angstroms,"
960 PRINT"calculate the contour length of the Drosophila DNA (in Angstroms)."
970 @ : @
980 PRINT"Your estimate of the contour length (in Angstroms) is...";
990  FOR J=1 TO 10
000  @ : NEXT J : INPUT V
```

```
5010 IF V<0.9*6000 THEN 5060
5020 IF V>1.1*6000 THEN 5100
5030 @ : @
5040 PRINT"Well calculated...the contour length is considered to be about 6000A"
5050 GOTO 5130
5060 @ : @
5070 PRINT"Your estimate for the contour length is too low...try again."
5080 IF T=1 THEN 4910
5090 GOTO 5130
5100 @ : @
5110 PRINT"Your estimate for the contour length is too high...try again."
5120 IF T=1 THEN 4910
5130 LET N=15 : GOSUB 75000
5140 LET T=0
5150 GOSUB 80000
5160 GOSUB 55000
5170 PRINT"From which source would you be most likely to extract the DNA as shown
5180 PRINT"in the frame shown."
5190 LET I=27 : GOSUB 97000
5200 GOSUB 97000
5210 @ : @ : GOSUB 70000
5220 PRINT"A    nucleus;"
5230 GOSUB 70000
5240 PRINT"B    mitochondria;"
5250 GOSUB 70000
5260 PRINT"C    chloroplasts;"
5270 GOSUB 70000
5280 PRINT"D    E.coli;"
5290 GOSUB 70000
5300 PRINT"E    T-even 'phage;"
5310 GOSUB 70000
5320 PRINT"F    Drosophila."
5330  FOR J=1 TO 7
5340  @ : NEXT J : INPUT B$
5350 IF B$="B"THEN 5460
5360 IF B$="C"THEN 5460
5370 PRINT"Answer ";
5380 PRINT TAB(7);
5390 PRINT B$;
5400 PRINT TAB(9);
5410 PRINT"is incorrect.  As a hint, first identify the type of tertiary"
5420 PRINT"structure present in the EM then think where such a form might be"
5430 @"found"
5440 IF T=1 THEN 5150
5450 GOTO 5580
5460 PRINT"You are quite correct in the answer you have given."
5470 PRINT
5480 PRINT"It is worthwhile noting, however, that answer ";
5490 IF B$="C"THEN 5520
5500 LET S$="C"
5510 GOTO 5530
5520 LET S$="B"
5530 PRINT TAB(46);
5540 PRINT S$;
5550 PRINT TAB(48);
5560 PRINT"is equally acceptable."
5570 PRINT"(Had you realised that yourself ?....if so, well done.)"
5580 LET N=16 : GOSUB 75000
5590 LET T=0
5600 GOSUB 80000
5610 PRINT"The frame shown here illustrates the open-circular form of PM2 virus."
5620 LET I=43 : GOSUB 97000
```

```
6630 PRINT"In this form there is a 'nick' or 'interruption' in one of the strands
6640 PRINT"of the double-stranded circular DNA.  The consequence of this is that"
6650 PRINT"the structure is relaxed.  When such an interruption is sealed there"
6660 PRINT"is a possibility of incorporating superhelical twists prior to the"
6670 PRINT"final covalent bond being formed.  If this occurs, then the tertiary"
6680 PRINT"structure that is formed is supercoiled or supertwisted DNA.  Such a"
6690 PRINT"structure for PM2 virus is shown in the next frame."
6700  FOR J=1 TO 6
6710  @ : NEXT J
6720 GOSUB 80000
6730 LET I=42 : GOSUB 97000
6740 @ : @
6750 PRINT"Note: very frequently, supercoiled DNA adopts a Y-shaped form.  (This"
6760 PRINT"is a consequence of the internal strain of the superhelical twists)."
6770  FOR J=1 TO 9
6780  @ : NEXT J : LET T=0
6790 GOSUB 80000
6800 GOSUB 55000
6810 PRINT"The mode of DNA replication has been shown to be:"
6820 LET I=4 : GOSUB 97000
6830 @ : @ : GOSUB 70000
6840 PRINT"A    conservative;"
6850 GOSUB 70000
6860 PRINT"B    semi-conservative;"
6870 GOSUB 70000
6880 PRINT"C    non-conservative;"
6890 GOSUB 70000
6900 PRINT"D    dispersive."
6910  FOR J=1 TO 9
6920  @ : NEXT J : INPUT B$ : IF B$="B"THEN 5980
6930 @ : @ : @
6940 PRINT
6950 PRINT"Try again, only this time THINK."
6960 IF T=1 THEN 5790
6970 GOTO 6020
6980  FOR N=1 TO 4
6990  @ : NEXT N
7000 PRINT"Yes, well done (it was an easy question, though).  Next we shall "
7010 PRINT"consider the experimental data for such a view."
7020 LET N=17 : GOSUB 75000
7030 LET T=0
7040 GOSUB 80000
7050 GOSUB 55000
7060 PRINT"This figure shows schematically three different modes of replication."
7070 PRINT
7080 PRINT"Identify the model for semi-conservative replication."
7090 @ : @
7100 LET I=5 : GOSUB 97000
7110  FOR N=1 TO 100
7120  NEXT N
7130 LET I=41 : GOSUB 97000
7140 @ : @ : GOSUB 70000
7150 PRINT"A    model A;"
7160 GOSUB 70000
7170 PRINT"B    model B;"
7180 GOSUB 70000
7190 PRINT"C    model C."
7200  FOR J=1 TO 8
7210  @ : NEXT J : INPUT B$ : IF B$="C"THEN 6340
7220 @ : @
7230 IF B$="A"THEN 6290
7240 PRINT"No, this is an example of DISPERSIVE replication.  Look more closely"
```

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6250 PRINT"at the frame again and see if you now agree....once you have, try the"
6260 PRINT"question again."
6270 IF T=1 THEN 6040
6280 GOTO 6380
6290 PRINT"No, this is an example of END-TO-END conservative replication.  Look"
6300 PRINT"closely at the frame again and see if you now agree....once you have"
6310 PRINT"try the question again."
6320 IF T=1 THEN 6040
6330 GOTO 6380
6340 @ : @
6350 PRINT"Yes, model C does indeed represent semi-conservative replication."
6360 PRINT"Model B was, as you might have guessed, dispersive - whilst model A"
6370 PRINT"was end-to-end conservative replication."
6380 LET N=18 : GOSUB 75000
6390 LET T=0
6400 GOSUB 80000
6410 GOSUB 55000
6420 @"What well-known experiment is outlined in the figure shown ?"
6430 LET I=40 : GOSUB 97000
6440 @ : @ : GOSUB 70000
6450 @"A    Watson and Crick;"
6460 GOSUB 70000
6470 @"B    Hershey and Chase;"
6480 GOSUB 70000
6490 @"C    Avery and McLeod;"
6500 GOSUB 70000
6510 @"D    Meselson and Stahl;"
6520 GOSUB 70000
6530 @"E    Cairns and De Lucia;"
6540 GOSUB 70000
6550 @"F    Kornberg and Chargaff."
6560  FOR J=1 TO 7
6570  @ : NEXT J : INPUT B$
6580 IF B$="D"THEN 6950
6590 IF B$="E"THEN 6890
6600 IF B$="C"THEN 6830
6610 IF B$="B"THEN 6760
6620 IF B$="A"THEN 6690
6630 @ : @
6640 @"No, sorry....these two scientists, although both active in the field"
6650 @"of nucleic acid chemistry, never actually worked together.  Try the"
6660 @"question again."
6670 IF T=1 THEN 6400
6680 GOTO 10000
6690 @ : @
6700 @"No, you are getting confused here.  Watson and Crick are best associ-"
6710 @"ated with the elucidation of the double helix and this was very"
6720 @"largely determined from known data rather than one unique experi-"
6730 @"ment.  Try the question again."
6740 IF T=1 THEN 6400
6750 GOTO 10000
6760 @ : @
6770 @"No, soory...Hershey and Chase are associated with the experiment"
6780 @"using doubly-labelled virus particles (S-35 in the coat protein"
6790 @"and P-32 in the viral DNA)....do you remember now ?"
6800 @"Try the question once again."
6810 IF T=1 THEN 6400
6820 GOTO 10000
6830 @ : @
6840 @"No, sorry...Avery and McLeod are associated with a classic experi-"
6850 @"ment which demonstrated genetic transformation...Do you remember"
6860 @"now ?  Try the question once again."
```

```
 6870 IF T=1 THEN 6400
 6880 GOTO 10000
 6890 @ : @
 6900 @"No, sorry...Cairns and De Lucia are best remembered for their exciting"
 6910 @"work on genetic mutations of E.coli which affected the enzymes involved"
 6920 @"in DNA replication (see later).  Try the question again."
 6930 IF T=1 THEN 6400
 6940 GOTO 10000
 6950 @ : @
 6960 @"Yes, well done.  The results of this classic experiment were used to"
 6970 @"provide evidence for a semi-conservative mode of replication."
 6980 LET N=19 : GOSUB 75000
 6990 @ : @ : @
10000 ON ERROR GOTO 10020
10010 CREATE"SCORE"
10020 OPEN\1\"SCORE"
10030 PUT\1\Q,N1,N2,S
10040  FOR N=1 TO 50
10050  PUT\1\O(N)
10060  NEXT N
10070 CLOSE
10080 RUN"PART2"
40000 LET X$="R" : LET Y=2 : GOSUB 97000
40010  FOR J=1 TO 3
40020  @ : NEXT J : STOP
55000 LET T=T+1 : IF T=1 THEN 55020
55010 RETURN
55015 RETURN
55020 LET Q=Q+1 : RETURN
60000 REM Subroutine for producing sides of box
60010  FOR I=1 TO 5
60020  GOSUB 70000
60030  PRINT"*"; : PRINT TAB(51);"*" : NEXT I : RETURN
70000 REM Subroutine for spacing
70010 PRINT TAB(20); : RETURN
75000 REM subroutine for evaluating assessment data
75010 IF T=1 THEN 75050
75020 LET S=S+0.33333 : LET N2=N2+1 : LET O(N)=0.5 : RETURN
75050 LET S=S+1 : LET N1=N1+1 : LET O(N)=1 : RETURN
80000 REM Subroutine for generating RETURN box
80010 @
80020 @TAB(60); : @"""""""""""" : @TAB(60);"* RETURN *" : @TAB(60);
80060 @""""""""""""; : INPUT B$
80080 IF B$=""THEN 80130
80090 IF B$="0"THEN 80150
80100 IF B$="S"THEN 80170
80120 GOTO 80020
80130  FOR J=1 TO 7
80132  @ : NEXT J : RETURN
80150 PRINT"Early exit from the program has been requested."
80160 GOTO 99999
80170 GOSUB 85000
80180 GOTO 80020
85000 REM subroutine for outputing assessment data
85010  FOR N=1 TO 10
85020  @ : NEXT N
85040 @TAB(5);"*************************************************************************"
85050 @TAB(5);"*"; : @TAB(67);"*"
85070 @USING"     * Total number of questions attempted                =   £££",Q;
85071 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
85100 @USING"     * Number of correct responses on first attempt       =   £££",N1;
85101 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
```

```
85130 @USING"     * Number of correct responses on second attempt   =   £££",N2;
85131 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
85150 LET B=100*S/Q
85160 @USING"     * Percentage score for this session              =   £££.££",B
85170 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
85190 @TAB(5);"*************************************************************"
85200  FOR N=1 TO 5
85210  @ : NEXT N : RETURN
97000 REM Routine to output microfiche address
97100 OUT 100,J+128
97110  FOR K=1 TO 100
97120  NEXT K
97130 OUT 100,I
97140 J=I
97150 RETURN
98000 OUT 116,255
98010 READ I
98020 OUT 116,I
98030 IF I=255 THEN 98100
98040  FOR I=1 TO 100
98050  NEXT I
98060 OUT 116,255
98070  FOR I=1 TO 100
98075  NEXT I
98090 GOTO 98010
98100  FOR N=1 TO 8
98110  @ : NEXT N
98130 @"                ******************************************"
98132 @"                *                                        *"
98134 @"                *          VIDEO SEGMENT FOLLOWS         *"
98136 @"                *                                        *"
98138 @"                *  Type S/RETURN to stop the programme   *"
98140 @"                *                                        *"
98142 @"                *  To restart, depress the RETURN key    *"
98144 @"                *                                        *"
98146 @"                ******************************************"
98147  FOR N=1 TO 8
98148  @ : NEXT N
98150 INPUT A$
98170 IF A$="S"THEN 98180
98171 IF A$="X"THEN 99194
98172 GOTO 99000
98180 OUT 116,7
98190  FOR I=1 TO 100
98195  NEXT I
98200 OUT 116,255
98300  FOR I=1 TO 100
98350  NEXT I
98400 INPUT A$
98410 GOTO 98170
99000 OUT 116,7
99100  FOR I=1 TO 100
99150  NEXT I
99175 OUT 116,255
99180  FOR I=1 TO 100
99190  NEXT I
99191 GOTO 98150
99194 OUT 116,4
99195  FOR I=1 TO 100
99196  NEXT I
99200 RETURN
99999 END
```

```
 20 DIM O(50)
 40 OPEN\1\"SCORE"
 50 GET\1\Q,N1,N2,S
 90  FOR N=1 TO 50
100  GET\1\O(N)
110  NEXT N
130 CLOSE
140 DIM B$(30)
170 LET L=27
180  FOR J=1 TO 10
190  @ : NEXT J
200 @TAB(L); : @"**************************"
210 @TAB(L); : @"*                        *"
220 @TAB(L); : @"*   DNA REPLICATION      *"
230 @TAB(L); : @"*                        *"
240 @TAB(L); : @"*        PART 2          *"
250 @TAB(L); : @"*                        *"
260 @TAB(L); : @"**************************"
270  FOR J=1 TO 6
280  @ : NEXT J
370 LET T=0
380 GOSUB 15000
390 GOSUB 12000
400 @"In this frame, you will see that, following isolation of the DNA, a"
410 @"solution of caesium chloride (CsCl) is used.  For what purpose ?"
420 @ : @ : GOSUB 13070
430 @"A    it helps to dissociate the DNA ;" : GOSUB 13070
440 @"B    it precipitates the DNA ;" : GOSUB 13070
450 @"C    it helps to visualise the DNA molecules ;" : GOSUB 13070
460 @"D    it prevents mutations occuring ;" : GOSUB 13070
470 @"E    it enhances DNA isolation by further" : GOSUB 13070
480 @"     deproteinising the sample ;" : GOSUB 13070
490 @"F    it facilitates separation by forming" : GOSUB 13070
500 @"     a gradient ;" : GOSUB 13070
510 @"G    it binds to the phosphate groups" : GOSUB 13070
520 @"     so forming a fluorescent complex." :  FOR J=1 TO 4
530  @ : NEXT J : INPUT B$ : IF B$="F"THEN 570                          again."
540 @USING"Your answer of £ is not very probable",B$; : @".  Try the question
550 IF T=1 THEN 380
560 GOTO 620
570  FOR J=1 TO 5
580  @ : NEXT J
590 @"Exactly !....under a centrifugal force (or centripetal) a solution of"
600 @"CsCl redistributes in the tube, so forming a density gradient.  The"
610 @"technique itself is termed ISOPYCNIC CENTRIFUGATION."
620 LET N=20 : GOSUB 14000
630 LET T=0
640 GOSUB 15000
650 GOSUB 12000
660 @"Also in this frame, you will see that the DNA is detected during "
670 @"centrifugation by use of uv-light.  At what wavelength would you"
680 @"expect to set the instrument ?"
690 @ : @ : GOSUB 13070
700 @"A    700nm ;" : GOSUB 13070
720 @"B    410nm ;" : GOSUB 13070
730 @"C    340nm ;" : GOSUB 13070
740 @"D    280nm ;" : GOSUB 13070
750 @"E    260nm ." :  FOR J=1 TO 7
760  @ : NEXT J : INPUT B$ :  FOR N=1 TO 4
770  @ : NEXT N : IF B$="E"THEN 940
780 IF B$="D"THEN 890
790 IF B$="C"THEN 850
```

```
800 @"No, the wavelength you have chosen lies in the visible region of the"
810 @"spectrum.  Nucleic acids are, however, colourless !  Try the question"
820 @"once again, bearing this in mind."
830 IF T=1 THEN 640
840 GOTO 960
850 @"No, you are probably getting confused between DNA and NAD+.  Try the"
860 @"question once again."
870 IF T=1 THEN 640
880 GOTO 960
890 @"No, whilst the DNA would probably have a detectable absorbance at this"
900 @"wavelength, it is not the most suitable choice (280nm is better suited"
910 @"for protein solutions).  With this in mind, try the question once again."
920 IF T=1 THEN 640
930 GOTO 960
940 @"Well done, this is indeed the correct wavelength for measuring DNA"
950 @"solutions."
960 LET N=21 : GOSUB 14000
970 LET T=0
980 GOSUB 15000
990 GOSUB 12000
1000 @"This frame shows schematically part of an experiment to determine"
1010 @"the mechanism of DNA replication.  The patterns obtained on replication,"
1020 @"as shown here, represent which generation ?"
1030 LET I=39 : GOSUB 17000
1040 @ : @
1050 GOSUB 13070
1060 @"A    first;" : GOSUB 13070
1070 @"B    second;" : GOSUB 13070
1090 @"C    infinite." :  FOR J=1 TO 8
1100  @ : NEXT J
1110 INPUT B$
1120  FOR N=1 TO 5
1130  @ : NEXT N
1140 IF B$="A"THEN 1180
1150 @"No, sorry...look again at the line drawing, then try again."
1160 IF T=1 THEN 980
1170 GOTO 1240
1180 @"Yes, well done...the first generation represents a crucial difference"
1190 @"between semi-conservative and conservative modes of replication.  As"
1200 @"you can see, with semi-conservative replication we would expect to see"
1210 @"only a single band on centrifugation whereas with conservative repli-"
1220 @"cation we would expect two bands in equal proportions."
1230 @"This is summarised in the frame shown."
1240 LET N=22 : GOSUB 14000
1250 LET T=0
1260 GOSUB 15000
1280 @"This frame illustrates typical results obtained from a Meselson and Stahl"
1290 @"experiment..."
1300 LET I=38 : GOSUB 17000
1310 @ : @
1330 @"Points to notice are as follows:"
1340 @TAB(5); : @"- at zero time, the DNA is present as 'heavy' DNA"
1350 @TAB(5); : @"- after four generations, can really only detect 'light' DNA"
1360 @TAB(5); : @"- after one generation, can only see one type of DNA and that"
1370 @TAB(5); : @"  is hybrid DNA (ie. one strand 'light' and the other 'heavy'"
1380 @TAB(5); : @"- for the band pattern obtained for all the different"
1390 @TAB(5); : @"  generation times, only one mode of replication is possible -"
1400 @TAB(5); : @"  semi-conservative."
1410  FOR J=1 TO 5
1420  @ : NEXT J
1430 LET T=0
1440 GOSUB 15000
```

```
450 GOSUB 12000
460 @"Which of the following statements concerning the Meselson-Stahl"
470 @"experiment is incorrect ?"
480 LET I=4 : GOSUB 17000
490 @ : @ : GOSUB 13070
500 @"A    DNA labelled with N-15 has a higher"
510 GOSUB 13070
520 @"     density than N-14 DNA;" : GOSUB 13070
540 @"B    heavy, light and hybrid DNA molecules"
550 GOSUB 13070
560 @"     can be separated by density gradient"
570 GOSUB 13070
580 @"     centrifugation;" : GOSUB 13070
590 @"C    hybrid DNA is composed of one parental" : GOSUB 13070
600 @"     strand and a newly-synthesised comple-" : GOSUB 13070
620 @"     mentary strand;" : GOSUB 13070
630 @"D    after a brief exposure (20 minutes) to" : GOSUB 13070
640 @"     N-15 ammonium chloride contained in the" : GOSUB 13070
650 @"     medium, the E. Coli are allowed to incub-" : GOSUB 13070
660 @"     ate for a long period in N-14 ammonium" : GOSUB 13070
680 @"     chloride and the radioactivity measured." : @
690 INPUT B$
700 IF B$="D"THEN 1760
710 @"Do you really think that this statement is incorrect ?" : @
720 @"Take your time, think clearly then try again." : @
730 IF T=1 THEN 1440
740 GOTO 1770
760 @"You are indeed quite correct...well done.  You can now continue."
770 LET N=23 : GOSUB 14000
780 LET T=0
790 GOSUB 15000
800 OUT 100,6
810  FOR N=1 TO 8
820  @ : NEXT N
840 @"                        **********************************"
850 @"                        *          AUDIO SEGMENT         *"
860 @"                        *  To pause, depress key P       *"
870 @"                        *  followed by RETURN key.       *"
880 @"                        **********************************"
890  FOR N=1 TO 7
900  @ : NEXT N
950 GOSUB 15000
970 GOSUB 12000
980 @"Type in the sequence of the DNA strand which is complementary to a"
990 @"segment of DNA with sequence:"
2000 @ : GOSUB 13070
2010 @"5' GAACTACGAGTTCA 3'"
2020 GOSUB 13070
2030 @"   ::::::::::::::" : @TAB(21);
2050 INPUT B$
2060  FOR J=1 TO 4
2070  @ : NEXT J
2080 IF B$="CTTGATGCTCAAGT"THEN 2180
2090 IF B$="TGAACTCGTAGTTC"THEN 2140
2100 @
2110 @"Check to make sure you have not made any typing errors, then try again."
2120 IF T=1 THEN 1950
2130 GOTO 2280
2140 @"The answer you have typed in assumes that the complementary strands"
2150 @"have similar polarity (ie. parallel).  This is not the case..try again."
2160 IF T=1 THEN 1950
2170 GOTO 2280
```

```
2180 @"Well done, although that was easy (wasn't it?).  The very fact that it"
2190 @"was easy led early workers to argue along the following lines:" : @ : @TAB
2200 @"If the DNA double helix was separated into individual" : @TAB(10);    (10);
2210 @"strands then it should be an easy matter to make copies" : @TAB(10);
2220 @"of both strands in the way that you have just done." : @ : @
2230 @"This being the case, the search was on for an enzyme that was capable"
2240 @"of catalysing such a process in vitro and in vivo.  (We shall see"
2250 @"later that there is quite a serious flaw in the rationale described)"
2260  FOR J=1 TO 5
2270  @ : NEXT J
2280 DATA 16,12,10,255
2290 GOSUB 18000
2300 LET N=24 : GOSUB 14000
2310 LET T=0
2320 GOSUB 15000
2330 @"The Role of DNA Polymerase I"
2340 @"**************************************" : @
2350 @"This was the first candidate for the role of 'DNA replicase' and is"
2360 @"also known as DNA-dependent DNA polymerase or the Kornberg enzyme." : @
2370 @"Kornberg and coworkers demonstrated in 1956 that DNA could be synthe-"
2380 @"sised by a cell-free extract containing the following requirements:"
2390 @TAB(10); : @"- the four deoxyribonucleotide 5'-triphosphates"
2400 @TAB(10); : @"- Mg ions" : @TAB(10);
2410 @"- denatured DNA template (calf thymus was used)" : @TAB(10);
2420 @"- the enzyme DNA polymerase I" : @ : @
2430 @"By using a radioactive deoxyribonucleotide (any of them) they"
2440 @"demonstrated that radioactive label was incorporated into an acid"
2450 PRINT"precipitable material which was identified as DNA."
2460 PRINT : PRINT : GOSUB 15000
2480 @"Nature of the Product" : @"************************"
2490 OUT 100,6
2500  FOR N=1 TO 8
2510  @ : NEXT N
2530 @"                          **********************************"
2540 @"                          *        AUDIO SEGMENT           *"
2550 @"                          *  To pause, depress key P       *"
2560 @"                          *  followed by RETURN key.       *"
2570 @"                          **********************************"
2580  FOR N=1 TO 7
2590  @ : NEXT N
2780 GOSUB 15000
2790 @"Earlier it was hinted that there was a flaw in the rationale which we"
2800 @"have so far been considering, i.e. that the two strands separate prior"
2810 @"to replication.......this comes to light if we consider the total"
2820 @"amount of energy that would be required to achieve this."
2830 @TAB(4);
2840 PRINT"-the average free energy to break a base-pair is "
2850 @TAB(4);
2860 PRINT" about 5-10 kJ/mol"
2870 @TAB(4);
2880 PRINT"-the average mwt of a DNA molecule is about 10E6 to 10E9"
2890 @TAB(4);
2900 PRINT"-the mwt of a base pair is about 700"
2910 @ : @"From this data we can calculate the free energy required to separate"
2920 @"the two strands...this turns out to be about 10E5 - 10E6 KJ/mol...a"
2930 @"lot of energy !!!"
2940 @"This could be rationalised by arguing that only a small amount was"
2950 @"unwound at a time, so forming a replication fork as shown (we shall"
2960 @"return to this consideration of the energetics of the process later)."
2970 LET I=5 : GOSUB 17000
3000 @ : @ : LET I=37 : GOSUB 17000
3010 GOSUB 15000
```

```
3020 GOSUB 12000
3030 LET I=4 : GOSUB 17000
3040 @"Nature of the Template for DNA Polymerase I"
3050 PRINT"****************************************"
3060 @ : @"So far we have only considered using DENATURED DNA as a template "
3070 @"i.e. single-stranded DNA.  When native double-stranded DNA was used,"
3080 @"however, the product formed had three peculiarities.  Identify these"
3090 @"from the list below:"
3100 @ : GOSUB 13070
3110 @"A    product shows branches;"
3120 GOSUB 13070
3130 PRINT"B    contained uracil in place of thymine;"
3140 GOSUB 13070
3150 PRINT"C    product was supercoiled;"
3160 GOSUB 13070
3170 PRINT"D    it had no biological activity;"
3180 GOSUB 13070
3190 PRINT"E    it was non-denaturable;"
3200 GOSUB 13070
3210 PRINT"F    it always ended up as poly A;"
3220 GOSUB 13070
3230 PRINT"G    it contained no purines (i.e. apurinic);"
3240  FOR J=1 TO 3
3250  @ : NEXT J
3260 @"Type in three letters of your choice e.g. ABC (the order does not matter)"
3270 @ : @ : INPUT B$
3280 IF B$="ADE"THEN 3380
3290 IF B$="AED"THEN 3380
3300 IF B$="DAE"THEN 3380
3310 IF B$="DEA"THEN 3380
3320 IF B$="EAD"THEN 3380
3330 IF B$="EDA"THEN 3380
3340 @ : @
3350 PRINT"No sorry, you have at least one option wrong...try again."
3360 IF T=1 THEN 3040
3370 GOTO 3420
3380 @"Well done, you got all three correct.  In a sense option A is the key"
3390 @"to explaining the other two observations.  This is summarized in the"
3400 PRINT"illustration shown."
3410 GOTO 3450
3420 @"No, you have got it wrong again.  Look at the illustration shown and"
3430 @"try to follow what is happening.  If still in doubt consult the"
3440 @"lecturer."
3450 LET N=25 : GOSUB 14000
3460 LET I=5 : GOSUB 17000
3480  FOR N=1 TO 100
3490  NEXT N
3500 LET I=33 : GOSUB 17000
3520 GOSUB 15000
3530 GOSUB 12000
3540 @"The following four frames illustrate the general scheme of DNA"
3550 @"replication in which an early event to occur is the formation of a"
3560 @"replication fork as shown..."
3570  FOR N=1 TO 10
3580  @ : NEXT N
3590  FOR N=1 TO 2500
3600  NEXT N
3610 LET I=37 : GOSUB 17000
3620  FOR N=1 TO 2000
3630  NEXT N
3640 LET I=36 : GOSUB 17000
3650  FOR N=1 TO 2000
```

```
3660  NEXT N
3670 LET I=35 : GOSUB 17000
3680  FOR N=1 TO 2000
3690  NEXT N
3700 LET I=34 : GOSUB 17000
3710  FOR N=1 TO 2000
3720  NEXT N
3730  FOR N=1 TO 7
3740  @ : NEXT N
3750 @"As we shall see, even this apparently simple process is an extremely"
3760 @"complicated event.  The types of questions to which we can address our-"
3770 @"selves might be...."
3780 @
3790 @"     Does the replication fork occur at one end of the DNA,"
3800 @"     at both ends or indeed, can it occur at any point in"
3810 @"     the molecule ?" : @
3820 @"     Which enzymes are involved in the initiation event ?" : @
3830 @"     Is the overall process any different for circular DNA"
3840 @"     molecules ?" : @ : @
3850 @"The answers to such questions will be considered in the following section.
3870 LET T=0
3880 LET I=4 : GOSUB 17000
3890 GOSUB 15000
3900 GOSUB 12000
3910  FOR N=1 TO 7
3920  @ : NEXT N
3930 @"From the considerations just discussed it became apparent that DNA"
3940 @"polymerase I was unlikely to be the replicase enzyme, although the"
3950 @"proponents for this enzyme argued that it may still be the replicase"
3960 @"but that it also requires one or more additional enzymes/proteins in"
3970 @"order that the process of replication can properly take place."
3980 @
3990 @"The downfall of DNA polymerase I as the replicase came from a study"
4000 @"of mutants of E. coli.   Which of the following mutants demonstrated"
4010 @"this fact conclusively ? :"
4020 @ : @
4030 @TAB(21); : @"A    pol A- ;"
4040 @TAB(21); : @"B    pol B- ;"
4050 @TAB(21); : @"C    pol C- ;"
4060 @TAB(21); : @"D    pol D- ;"
4070 @TAB(21); : @"E    sof ;"
4080 @TAB(21); : @"F    dut :"
4090  FOR N=1 TO 3
4100  @ : NEXT N
4110 INPUT B$
4120 IF B$="C"THEN 4260
4130 IF B$="E"THEN 4200
4140 IF B$="F"THEN 4200
4150 @"This is not the correct answer, this results from this mutant with"
4160 @"respect to the role of DNA polymerase I are still inconclusive."
4170 @ : @"Try the question one more time."
4180 IF T=1 THEN 3890
4190 GOTO 4290
4200 @"This is not the correct answer.  This particular mutant was related"
4210 @"to the incorporation of dUTP into nascent DNA and therefore has no"
4220 @"relevence with the question in hand."
4230 @ : @"Try the question one more time."
4240 IF T=1 THEN 3890
4250 GOTO 4290
4260 @"Well done, this is indeed the correct answer.  This particular mutant"
4270 @"is the only one that was CONCLUSIVE with respect to the replicase"
4280 @"role being other than DNA polymerase I."
```

```
4290 LET N=26 : GOSUB 14000
4300 LET T=0
4310 GOSUB 15000
4320 GOSUB 12000
4330  FOR N=1 TO 7
4340  @ : NEXT N
4350 @"Having established that DNA polymerase I does not act as the replicase"
4360 @"enzyme in the cell, a detailed study with the mutant pol C- revealed"
4370 @"that the replicase function was carried out by which enzyme ?"
4380 @ : @
4390 @TAB(17); : @"A    DNA polymerase II ;"
4400 @TAB(17); : @"B    DNA polymerase III ;"
4410 @TAB(17); : @"C    DNA polymerase IV ;"
4420 @TAB(17); : @"D    Phosphodiesterase;"
4430 @TAB(17); : @"E    Reverse transcriptase."
4440  FOR N=1 TO 5
4450  @ : NEXT N
4460 INPUT B$
4470 IF B$="A"THEN 4560
4480 IF B$="B"THEN 4620
4490 IF B$="C"THEN 4680
4500  FOR N=1 TO 4
4510  @ : NEXT N
4520 @"Absolute RUBBISH !!!!!  Try the question again, only this time kindly"
4530 @"engage brain before selecting an answer."
4540 IF T=1 THEN 4310
4550 GOTO 4720
4560  FOR N=1 TO 4
4570  @ : NEXT N
4580 @"No, this is incorrect....the mutant polB- demonstrated that DNA poly-"
4590 @"merase was not the replicase enzyme.  Try the question once again."
4600 IF T=1 THEN 4310
4610 GOTO 4720
4620  FOR N=1 TO 4
4630  @ : NEXT N
4640 @"Yes indeed...DNA polymerase III is now thought to be the replicase"
4650 @"enzyme in vivo although as we shall see, it does also require the"
4660 @"help of other enzymes and proteins."
4670 GOTO 4720
4680  FOR N=1 TO 4
4690  @ : NEXT N
4700 @"There is no such enzyme as DNA polymerase IV in E.coli....Try again."
4710 IF T=1 THEN 4310
4720 LET N=26 : GOSUB 14000
4730 LET T=0
4740 GOSUB 15000
4750 GOSUB 12000
4760 LET I=5 : GOSUB 17000
4770 @"Shown here is a photograph of Reiji Okazaki (1930-75).  What contri-"
4780 @"bution did he make to the knowledge of the molecular events which"
4790 @"occur during DNA replication ?"
4800 LET I=32 : GOSUB 17000
4810 @ : @
4820 @TAB(14);
4830 @"A   DNA polymerase I is not the replicase;"
4840 @TAB(14);
4850 @"B   DNA polymerase III is the replicase;"
4860 @TAB(14);
4870 @"C   discovered polA- mutants;"
4880 @TAB(14);
4890 @"D   replication involves discontinuous synthesis;"
4900 @TAB(14);
```

```
4910 @"E   devised nearest-neighbour frequency analysis;"
4920 @TAB(14);
4930 @"F   uracil is removed by excision-repair."
4940  FOR J=1 TO 5
4950  @ : NEXT J
4960 INPUT B$
4970 IF B$="D"THEN 5090
4980 IF B$="E"THEN 5160
4990 IF B$="C"THEN 5210
5000  FOR J=1 TO 5
5010  @ : NEXT J
5020 @"No, your choice of option ";
5030 @TAB(27);
5040 @B$;
5050 @TAB(29);
5060 @"is incorrect.  Try the question one more time."
5070 IF T=1 THEN 4740
5080 GOTO 5250
5090  FOR J=1 TO 5
5100  @ : NEXT J
5110 @"Well done...Okazaki first predicted the need for discontinuous synthesis"
5120 @"during DNA replication because the polymerase could operate in one"
5130 @"direction only...5'-->3'.  He then went on to prove this requirement"
5140 @"experimentally."
5150 GOTO 5250
5160  FOR J=1 TO 5
5170  @ : NEXT J
5180 @"No, you are confusing Okazaki with Kornberg.....Try the question again."
5190 IF T=1 THEN 4740
5200 GOTO 5250
5210  FOR J=1 TO 5
5220  @ : NEXT J
5230 @"No, you are confusing Okazaki with Cairns and De Lucia...Try again."
5240 IF T=1 THEN 4740
5250 LET N=27 : GOSUB 14000
5260 @ : @ : @
0000 ON ERROR GOTO 10020
0010 CREATE"SCORE"
0020 OPEN\1\"SCORE"
0030 PUT\1\Q,N1,N2,S
0040  FOR N=1 TO 50
0050  PUT\1\O(N)
0060  NEXT N
0070 CLOSE
0080 RUN"PART3"
2000 REM Subroutine to evaluate total number of questions and attempts
2010 REM
2020 REM ************************************************************************
2030 REM
2040 LET T=T+1 : IF T=1 THEN 12060
2050 RETURN
2060 LET Q=Q+1 : RETURN
2070 REM
2080 REM
3000 REM Subroutine for producing sides of box
3010 REM
3020 REM ************************************************************************
3030 REM
3040  FOR I=1 TO 5
3050  GOSUB 13070
3060  PRINT"*"; : PRINT TAB(51);"*" : NEXT I : RETURN
3070 REM Subroutine for spacing
```

```
3080 PRINT TAB(20); : RETURN
3090 REM
3100 REM
4000 REM Subroutine for evaluating assessment data
4010 REM
4020 REM ************************************************************************
4040 REM
4050 IF T=1 THEN 14070
4060 LET S=S+0.33333 : LET N2=N2+1 : LET O(N)=0.5 : RETURN
4070 LET S=S+1 : LET N1=N1+1 : LET O(N)=1 : RETURN
4080 REM
4090 REM
5000 REM Subroutine for generating RETURN box
5010 REM
5020 REM ************************************************************************
5030 REM
5040 @
5050 @TAB(60); : @"************" : @TAB(60);"* RETURN *" : @TAB(60);
5060 @"************"; : INPUT B$
5070 IF B$=""THEN 15140
5080 IF B$="O"THEN 15180
5090 IF B$="S"THEN 15200
5100 IF B$="P"THEN 15120
5110 GOTO 15050
5120 OUT 100,5
5130 GOTO 15140
5140  FOR J=1 TO 7
5150  @ : NEXT J : RETURN
5180 PRINT"Early exit from the program has been requested."
5190 GOTO 20000
5200 GOSUB 16000
5210 GOTO 15050
5220 REM
5230 REM
6000 REM Subroutine for outputing assessment data
6010 REM
6020 REM ************************************************************************
6030 REM
6040  FOR N=1 TO 10
6050  @ : NEXT N
6060 @TAB(5);"************************************************************************"
6070 @TAB(5);"*"; : @TAB(67);"*"
6080 @USING"     * Total number of questions attempted              =   £££",Q;
6090 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
6100 @USING"     * Number of correct responses on first attempt     =   £££",N1;
6110 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
6120 @USING"     * Number of correct responses on second attempt    =   £££",N2;
6130 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
6140 @USING"     * Percentage score for this session               =   £££.££",10
6150 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"                              )*S/(
6160 @TAB(5);"************************************************************************"
6170  FOR N=1 TO 5
6180  @ : NEXT N : RETURN
6190 REM
6200 REM
7000 REM Routine to output microfiche address
7010 REM
7020 REM ************************************************************************
7030 REM
7120 OUT 100,J+128
7130  FOR K=1 TO 40
7140  NEXT K
```

```
7150 OUT 100,I
7160 J=I
7170 RETURN
7180 REM
7190 REM
8000 REM Routine to output video segment address
8010 REM
8020 REM ************************************************************************
8030 REM
8040 OUT 116,255
8050 READ I
8060 OUT 116,I
8070 IF I=255 THEN 18140
8080  FOR I=1 TO 120
8090  NEXT I
8100 OUT 116,255
8110  FOR I=1 TO 120
8120  NEXT I
8130 GOTO 18050
8140  FOR N=1 TO 8
8150  @ : NEXT N
8160 @"                ****************************************"
8170 @"                *                                      *"
8180 @"                *         VIDEO SEGMENT FOLLOWS        *"
8190 @"                *                                      *"
8200 @"                *  Type S/RETURN to stop the programme *"
8210 @"                *                                      *"
8220 @"                *  To restart, depress the RETURN key  *"
8230 @"                *                                      *"
8240 @"                ****************************************"
8250  FOR N=1 TO 8
8260  @ : NEXT N
8270 INPUT A$
8280 IF A$="S"THEN 18310
8290 IF A$="X"THEN 18450
8300 GOTO 18380
8310 OUT 116,7
8320  FOR I=1 TO 100
8330  NEXT I
8340 OUT 116,255
8350  FOR I=1 TO 100
8360  NEXT I
8370 GOTO 18270
8380 OUT 116,7
8390  FOR I=1 TO 100
8400  NEXT I
8410 OUT 116,255
8420  FOR I=1 TO 100
8430  NEXT I
8440 GOTO 18270
8450 OUT 116,4
8460  FOR I=1 TO 100
8470  NEXT I
8480 OUT 116,255
8490  FOR I=1 TO 100
8500  NEXT I
8510 RETURN
20000 END
```

```
 10 DIM O(50)
 20 OPEN\1\"SCORE"
 30 GET\1\Q,N1,N2,S
 40  FOR N=1 TO 50
 50  GET\1\O(N)
 60  NEXT N
 70 CLOSE
 80 DIM B$(30),C$(30)
 90 LET L=27
100  FOR J=1 TO 10
110  @ : NEXT J
120 @TAB(L); : @"**************************"
130 @TAB(L); : @"**                      **"
140 @TAB(L); : @"**   DNA REPLICATION    **"
150 @TAB(L); : @"**                      **"
160 @TAB(L); : @"**        PART 3        **"
170 @TAB(L); : @"**                      **"
180 @TAB(L); : @"**************************"
190  FOR J=1 TO 6
200  @ : NEXT J
210 LET T=0
220 GOSUB 15000
230 GOSUB 12000
240 @"The frame shown illustrates three possible mechanisms of DNA"
250 @"replication  (the picture is upside down..that is the way it"
260 @"was copied).  Which of these models is now thought to be correct ?"
270 LET I=48 : GOSUB 17000
280 @ : @ : @
290 @TAB(28);
300 @"A   model 1;"
310 @TAB(28);
320 @"B   model 2;"
330 @TAB(28);
340 @"C   model 3."
350  FOR J=1 TO 7
360  @ : NEXT J
370 INPUT B$
380 IF B$="A"THEN 440
390  FOR J=1 TO 5
400  @ : NEXT J
410 @"No, your choice of models is incorrect...try the question once again."
420 IF T=1 THEN 220
430 GOTO 500
440  FOR J=1 TO 5
450  @ : NEXT J
460 @"Yes, well done, we have continuous synthesis on the leading strand and"
470 @"discontinuous synthesis on the lagging strand."
480  FOR J=1 TO 8
490  @ : NEXT J
500 LET N=28 : GOSUB 14000
510 LET T=0
520 GOSUB 15000
530 GOSUB 12000
540 LET I=49 : GOSUB 17000
550 @"The figure shown illustrates the various processes that occur at a"
560 @"replication fork."
570 @
580 @"Using the table of enzymes shown below,"
590 @
600 @"    1...DNA polymerase I                5...DNA ligase"
610 @"    2...DNA polymerase II               6...RNA polymerase"
620 @"    3...DNA polymerase III              7...unwinding enzyme"
```

```
630 @"    4...DNA gyrase                    8...HD-protein"
640 @ : @
650 @"answer the following questions :"
660 @
670 @"Which enzyme acts at the point marked :"
680 @
690 @"                    A   synthesis of new strand;"
700 @"                    B   swivel."
710 @ : @
720 INPUT L; : INPUT M
730 IF L=3 THEN 760
740 @ : @ : @ : @"Part A.....................................incorrect"
760 IF M=4 THEN 800
770 @ : @ : @ : @"Part B.....................................incorrect"
780 IF T=1 THEN 520
790 GOTO 850
800 IF L£3 THEN 780
810 @ : @ : @ : @"Well done, both questions answered correctly !!"
820 @ : @
850 LET N=29 : GOSUB 14000
860 GOSUB 15000
870 @"Shown here are the possible energetic contributions to helix unwinding."
880 @
890 @"HDP stands for helix-destabilising protein.  The arrows show the"
900 @"expected direction of the motion generated by the unwinding enzyme"
910 @"and DNA gyrase.  The assignment of unwinding enzyme to the lagging"
920 @"side of the fork is arbitrary."
930 LET I=50 : GOSUB 17000
940  FOR J=1 TO 10
950  @ : NEXT J
960 LET T=0
980 GOSUB 15000
990 GOSUB 12000
1000 @ : @ : @
1010 LET I=51 : GOSUB 17000
1020 @"If replication originates at a point within the DNA molecule, two modes"
1030 @"of replication can occur.  These are UNIDIRECTIONAL replication and"
1040 @"BIDIRECTIONAL replication as shown in the following illustration."
1050 @ : @ : @
1070 @"Which has been shown to occur in vivo ?"
1080 @
1090 @"                    A   unidirectional;"
1100 @"                    B   bidirectional."
1110  FOR J=1 TO 7
1120  @ : NEXT J
1130 INPUT B$
1140 IF B$="B"THEN 1210
1150 @ : @ : @ : @
1160 @"No, this is not the case as can be seen from the radioactive labelling"
1170 @"studies of Prescott.   Clearly from such electron micrographs the"
1180 @"process of replication must be taking place in both directions."
1200 GOTO 1250
1210 @ : @ : @ : @
1220 @"Yes, well done.....the experimental proof came, as you probably"
1230 @"know, from the labelling studies of Prescott as shown in the frame."
1250  FOR J=1 TO 6
1260  @ : NEXT J
1270 LET I=52 : GOSUB 17000
1300 @ : @
1310 GOSUB 15000
1320 @ : @ : @
1330 @"The same is also true for circular DNA molecules as can be seen in"
```

```
1340 @"the figure shown on the microfiche viewer."
1350 LET I=53 : GOSUB 17000
1360  FOR J=1 TO 12
1370  @ : NEXT J
1380 LET N=30 : GOSUB 14000
1390 LET T=0
1400 GOSUB 15000
1410 GOSUB 12000
1420 @ : @ : @
1430 @"The figure now illustrated demonstrates an extension of this thinking."
1440 @ : @
1450 LET I=54 : GOSUB 17000
1460 @"What process is being illustrated in this figure...?"
1470 @
1480 @"              A   local unfolding caused by AT-rich regions;"
1490 @"              B   excision-repair of uracil residues;"
1500 @"              C   formation of cyclic DNA from linear DNA;"
1510 @"              D   multiple origins of replication;"
1520 @"              E   rolling circle model of replication."
1530  FOR J=1 TO 5
1540  @ : NEXT J
1550 INPUT B$
1560 IF B$="D"THEN 1700
1570 IF B$="A"THEN 1640
1580  FOR J=1 TO 5
1590  @ : NEXT J
1600 @"You would seem to be quite markedly off-track...think carefully, then"
1610 @"try again."
1620 IF T=1 THEN 1400
1630 GOTO 1780
1640  FOR J=1 TO 5
1650  @ : NEXT J
1660 @"This is certainly a possibility although the letters 'O' should have"
1670 @"suggested another possibility....try again with this in mind."
1680 IF T=1 THEN 1400
1690 GOTO 1780
1700  FOR J=1 TO 5
1710  @ : NEXT J
1720 @"That was easy, although well done on getting it correct..The fact"
1730 @"that this does indeed occur in vivo is illustrated in the frame"
1740 @"now shown."
1750  FOR J=1 TO 7
1760  @ : NEXT J
1770 LET I=55 : GOSUB 17000
1780 LET N=31 : GOSUB 14000
1790 LET T=0
1800 GOSUB 15000
1810 GOSUB 12000
1820 @"The frame shown represents an electron micrograph of a replicating"
1830 @"bacteriophage T7 DNA molecule."
1840 LET I=56 : GOSUB 17000
1850 @ : @ : @
1860 @"Which of the following observations can be deduced from the micro-"
1870 @"graph....?"
1880 @
1890 @TAB(10);
1900 @"A   T7 DNA is an open cyclic structure;"
1910 @TAB(10);
1920 @"B   T7 replicates by the rolling circle model;"
1930 @TAB(10);
1940 @"C   the DNA is replicating from the 3' end;"
1950 @TAB(10);
```

```
1960 @"D   T7 DNA contains superhelical twists;"
1970 @TAB(10);
1980 @"E   the DNA is replicating."
1990  FOR J=1 TO 5
2000  @ : NEXT J
2010 INPUT B$
2020 IF B$="E"THEN 2090
2030  FOR J=1 TO 5
2040  @ : NEXT J
2050 @"No, no, no......it really is not that difficult.  Think of what we"
2060 @"are considering then try again."
2070 IF T=1 THEN 1800
2080 GOTO 2160
2090  FOR J=1 TO 5
2100  @ : NEXT J
2110 @"Yes, well done...the clue came from the distinct feature of the"
2120 @"replication bubble, although as we shall see later there are"
2130 @"other explanations for such a feature."
2140  FOR J=1 TO 6
2150  @ : NEXT J
2160 LET N=32 : GOSUB 14000
2170 LET T=0
2180 GOSUB 15000
2190 GOSUB 12000
2200 @"This frame shows a molecule of eukaryotic nuclear DNA from Drosophila"
2210 @"melanogaster.  Which TWO of the following statements do you think are"
2220 @"valid."
2230 LET I=57 : GOSUB 17000
2240 @ : @ : @
2250 GOSUB 13070
2260 @"A    the DNA is open cyclic;" : GOSUB 13070
2270 @"B    the DNA is closed cyclic;" : GOSUB 13070
2280 @"C    the DNA contains superhelical twists;" : GOSUB 13070
2290 @"D    the DNA is single-stranded linear;" : GOSUB 13070
2300 @"E    the DNA is double-stranded linear;" : GOSUB 13070
2310 @"F    the DNA is replicating;" : GOSUB 13070
2320 @"G    replication is by rolling circle model;" : GOSUB 13070
2330 @"F    the DNA is concatenated."
2340 @ : @
2350 INPUT B$; : INPUT C$
2360 IF B$="E"THEN 2400
2370 IF B$="F"THEN 2400
2380 @ : @
2390 @"Your first choice is incorrect.....try again."
2400 IF C$="E"THEN 2450
2410 IF C$="F"THEN 2450
2420 @ : @
2430 @"Your second choice is incorrect.....try again."
2440 IF T=1 THEN 2180
2450 @ : @
2460 @"Yes, well done...both statements correctly identified."
2470 LET N=33 : GOSUB 14000
2480 LET T=0
2490 GOSUB 15000
2500 GOSUB 12000
2510 @"On the same frame, what features are exemplified by the regions"
2520 @"labelled A,B,C and D ?"
2530 @ : @ : @
2540 GOSUB 13070
2550 @"A    replication bubbles or eyes;" : GOSUB 13070
2560 @"B    base intercalation;" : GOSUB 13070
2570 @"C    catenation;" : GOSUB 13070
```

```
2580 @"D    concatenation;" : GOSUB 13070
2590 @"E    open circle tertiary structure;" : GOSUB 13070
2600 @"F    closed circle tertiary structure."
2610  FOR J=1 TO 7
2620  @ : NEXT J
2630 INPUT B$
2640 IF B$="A"THEN 2860
2650 IF B$="B"THEN 2810
2660 IF B$="C"THEN 2760
2670 @ : @
2680 @"Look carefully at the electron micrograph and you should be able to"
2690 @"see that the structure is linear....one end of the DNA is apparent"
2700 @"in the bottom-centre of the frame.  Try the question once again."
2710 GOTO 2840
2720 @ : @
2730 @"No, concatenated DNA is a long linear structure without the 'loops'."
2740 @"Try the question once again."
2750 GOTO 2840
2760 @ : @
2770 @"Catenated DNA looks like the links on a chain.  Whilst this electron"
2780 @"micrograph does have 'loops', these do not really appear to be"
2790 @"linked in the correct way.  Try the question once again."
2800 GOTO 2840
2810 @ : @
2820 @"No, base intercalation would never result in the type of structure"
2830 @"shown in this electron micrograph.  Try the question once again."
2840 IF T=1 THEN 2490
2850 GOTO 2910
2860 @ : @
2870 @"Yes, well done.  The multiple initiation sites for the replication of"
2880 @"DNA are clearly visible in the electron micrograph."
2890  FOR J=1 TO 9
2900  @ : NEXT J
2910 LET N=34 : GOSUB 14000
2930 GOSUB 15000
2950 LET I=58 : GOSUB 17000
2960 @ : @
2970 @"A schematic illustration of the origin and fate of multiple replication"
2980 @"sites is shown on the microfiche viewer.  Thus bidirectional synthesis"
2990 @"from each origin of replication proceed until they merge with another"
3000 @"replicon or with the end of the DNA chain."
3010  FOR J=1 TO 8
3020  @ : NEXT J
3030 LET T=0
3040 GOSUB 15000
3050 GOSUB 12000
3060 @ : @ : @
3070 @"What is the name given to the feature indicated between the arrows in"
3080 @"the electron micrograph of mouse L-cell mitochondrial DNA ?"
3090 LET I=59 : GOSUB 17000
3100 @ : @ : @
3110 GOSUB 13070
3120 @"A    catenane;" : GOSUB 13070
3130 @"B    concatenane;" : GOSUB 13070
3140 @"C    replication bubble;" : GOSUB 13070
3150 @"D    promotor site;" : GOSUB 13070
3160 @"E    palindrome."
3170  FOR J=1 TO 5
3180  @ : NEXT J
3190 INPUT B$
3200 IF B$="C"THEN 3320
3210 IF B$="A"THEN 3260
```

```
3220 @ : @
3230 @"No, your answer is not correct.  Try the question once again..it really"
3240 @"is not that difficult !!!"
3250 GOTO 3300
3260 @ : @ : @
3270 @"Whilst it is possible that the image shown in the electron micrograph"
3280 @"could represent catenated DNA, the question specifically referred to"
3290 @"'the feature between the arrows'.  With this in mind, try once again."
3300 IF T=1 THEN 3040
3310 GOTO 3370
3320 @ : @ : @
3330 @"Yes indeed, this is a replication bubble or eye....in this case on a"
3340 @"circular DNA molecule."
3350  FOR J=1 TO 7
3360  @ : NEXT J
3370 LET N=35 : GOSUB 14000
3380 GOSUB 15000
3390 LET I=75 : GOSUB 17000
3400 @"Electron micrographs of the type that you have just encountered are"
3410 @"to be interpreted with considerable caution.  For example, in the"
3420 @"schematic illustration shown, you may think that each of the 'loops'"
3430 @"represent a single replication bubble.  In fact they do not....only"
3440 @"the area between the arrows is a replication bubble, the rest are"
3450 @"caused by partial denaturation of the DNA (at AT-rich regions)."
3460 @ : @"Thus, be very careful when interpreting such figures"
3470  FOR J=1 TO 6
3480  @ : NEXT J
3490 LET T=0
3500 GOSUB 15000
3510 GOSUB 12000
3520 @ : @ : @
3530 @"Consider the electron micrograph as shown in this frame."
3540 @ : LET I=74 : GOSUB 17000
3550 @"What deductions can you make from such a structure ?"
3560 @ : @ : @
3570 GOSUB 13070
3580 @"A    supercoiling;" : GOSUB 13070
3590 @"B    multiple replication sites;" : GOSUB 13070
3600 @"C    rolling circle model."
3610  FOR J=1 TO 8
3620  @ : NEXT J
3630 INPUT B$
3640 IF B$="B"THEN 3690
3650 @ : @
3660 @"No, your answer is incorrect...try once more"
3670 @ : @ : IF T=1 THEN 3500
3680 GOTO 3850
3690 @ : @
3700 @"Whilst it may well look as though this is multiple replication sites,"
3710 @"it is in fact an electron micrograph of a heteroduplex DNA formed by"
3720 @"hybridisation of DNA molecules extracted from the E.coli 'phages, T2"
3730 @"and T4."
3740 @ : @"Such a heteroduplex map shows the extent of matching and non-matching"
3750 @"regions.  The clue to distinguishing between heteroduplex loops and"
3760 @"replication bubbles is to examine the length of the strands on either"
3770 @"side of the loop....if these differ in size then we have a hetero-"
3780 @"duplex map....if they are of the same length then both interpretations"
3790 @"are possible."
3800 @ : @"In this frame, the strands on either side of the largest loop (at"
3810 @"12 O'clock) can be seen to differ in length, hence are not replication"
3820 @"bubbles."
3830  FOR J=1 TO 4
```

```
3840  @ : NEXT J
3850 LET N=36 : GOSUB 14000
3860 GOSUB 15000
3870  FOR J=1 TO 7
3880  LET I=73 : GOSUB 17000
3890  @ : NEXT J
3900 @"Another example of a heteroduplex map is shown in this frame."
3910  FOR J=1 TO 12
3920  @ : NEXT J
3930 GOSUB 15000
3940 @ : @ : @
3950 @"Yet another example of this type of electron micrograph is shown."
3960 @ : LET I=72 : GOSUB 17000
3970 @"Once again the interpretation might that the region between the arrows"
3980 @"labelled A and B is a bubble formed during replication.  This is, in"
3990 @"fact, not the case with this sample.  Instead it is a mitochondrial"
4000 @"DNA from Drosophila which has been heated to 40 C for ten minutes in"
4010 @"0.05M sodium phosphate + 10% formaldehyde to partially denature the"
4020 @"molecules.  The region between the arrows is in fact a region rich in"
4030 @"A and T residues."
4040  FOR J=1 TO 6
4050  @ : NEXT J
4060 GOSUB 15000
4070  FOR J=1 TO 5
4080  @ : NEXT J
4090 @"The next subtopic to be dealt with is the replication of circular DNA."
4100 @
4110 @"One of the first considerations that we must make is whether we are"
4120 @"dealing with single-stranded cyclic DNA or double-stranded cyclic DNA."
4130 @ : @
4140 LET I=71 : GOSUB 17000
4150 @"We shall deal in a single frame with the mode of replication of single-"
4160 @"stranded cyclic DNA and this is two-step process is illustrated in the"
4170 @"frame shown for QX174."
4180 @"Thus the parent strand is used as a template for the synthesis of a"
4190 @"complementary strand (labelled as -) using DNA polymerase and ligase."
4200 @"In this in vitro experiment, the workers took the double-stranded"
4210 @"product (known as the replicative form) and introduced nicks in the"
4220 @"DNA strands.  Since dBrUTP was used, the (-) strand was more dense"
4230 @"in the centrifuge and so could be easily isolated.  The synthetic"
4240 @"(-) strand could then be used to synthesise a replica of the original"
4250 @"parent strand.  This process was achieved in vitro and it is now"
4260 @"generally accepted that this mode of replication occurs in vivo."
4270 @ : @
4280 LET T=0
4290 GOSUB 15000
4300 GOSUB 12000
4310 @ : @ : @
4320 @"The following frame shows an autoradiograph of the intact replicating"
4330 @"chromosome of E.coli which has been allowed to incorporate tritiated"
4340 LET I=68 : GOSUB 17000
4350 @"thymine into its DNA for slightly less than two generation periods."
4360 @ : @"What can you say about the replication of E.coli DNA ?"
4370 @ : @
4380 GOSUB 13070
4390 @"A    cyclic strands are kept intact during" : GOSUB 13070
4400 @"     replication;" : GOSUB 13070
4410 @"B    cyclic stands are converted to a linear" : GOSUB 13070
4420 @"     structure then replicated."
4430  FOR J=1 TO 8
4440  @ : NEXT J
4450 INPUT B$
```

```
4460 IF B$="A"THEN 4510
4470 @ : @ : @"No, look carefully at the micrograph...do you see a linear"
4480 @"structure anywhere in the field of view.  Try once again."
4490 IF T=1 THEN 4290
4500 GOTO 4570
4510 @ : @ : @
4520 LET I=67 : GOSUB 17000
4530 @"Yes, although that was not too difficult.  A schematic interpretation"
4540 @"of the replication process is shown in the frame now showing."
4550  FOR J=1 TO 9
4560  @ : NEXT J
4570 LET N=37 : GOSUB 14000
4580 GOSUB 15000
4590 @ : @ : @
4600 LET I=69 : GOSUB 17000
4610 @"The frame now shown illustrates the replication of cyclic DNA"
4620 @"according to the mechanism proposed by Cairns in 1963.  The two"
4630 @"circles are joined at a ball and socket joint known as the"
4640 @"'swivel'.  As shown here, replication proceeds counter-clockwise."
4650  FOR J=1 TO 8
4660  @ : NEXT J
4670 GOSUB 15000
4680 @ : @ : @
4690 LET I=70 : GOSUB 17000
4700 @"The figure shown here illustrates in more detail Cairns' swivel"
4710 @"mechanism during replication of double-stranded circular DNA as"
4720 @"described in 1963."
4730 @ : @"The filled-in circle labelled A represents unwinding enzyme."
4740  FOR J=1 TO 4
4750  @ : NEXT J
4760 @"Consider this frame carefully and decide whether the scheme needs"
4770 @"to be modified in the light of our knowledge of replication of"
4780 @"double-stranded linear DNA."
4790  FOR J=1 TO 4
4800  @ : NEXT J
4810 GOSUB 15000
4820 @ : @ : @
4830 LET I=66 : GOSUB 17000
4840 @"If we consider the growth of the replication fork during DNA"
4850 @"replication in double-stranded cyclic DNA, Then two mechanisms"
4860 @"are theoretically possible..unidirectional growth or bidirectional"
4870 @"growth as shown schematically in the frame."
4880 @
4890 @"If we extrapolate our findings for the replication of double-stranded"
4900 @"linear DNA, then we might expect that the in vivo mechanism is the"
4910 @"bidirectional model.  This has been shown to be the case using"
4920 @"similar radio-labelling experiments as described earlier in the"
4930 @"program."
4940  FOR J=1 TO 6
4950  @ : NEXT J
4960 LET T=0
4970 GOSUB 15000
4980 GOSUB 12000
4990 @ : @ : @
5000 @"It has been demonstrated that there are a number of discrete models"
5010 @"for the replication of double-stranded cyclic DNA."
5020 @ : @"Which of the following does not represent one such model ?"
5030 LET I=4 : GOSUB 17000
5040 @ : @ : @ : GOSUB 13070
5050 @"A    butterfly mechanism;" : GOSUB 13070
5060 @"B    Cairns' swivel;" : GOSUB 13070
5070 @"C    rolling circle;" : GOSUB 13070
```

```
5080 @"D    D-loop mechanism;" : GOSUB 13070
5090 @"E    sigma cycle;" : GOSUB 13070
5100 @"F    theta structure model."
5110  FOR J=1 TO 5
5120  @ : NEXT J
5130 INPUT B$
5140 IF B$="E"THEN 5260
5150 IF B$="B"THEN 5210
5160 @ : @ : @
5170 @"No, answer "; : @TAB(11); : @B$; : @TAB(13);
5180 @"is indeed a mechanism for the replication of"
5190 @"double-stranded cyclic DNA as we shall see later.  Try once again."
5200 GOTO 5240
5210 @ : @ : @
5220 @"No, it is surprising that you think this, particularly since we have"
5230 @"only just dealt with Cairns' swivel mechanism.  Try once again."
5240 IF T=1 THEN 4970
5250 GOTO 5330
5260 @ : @ : @
5270 @"Yes, well done...the sigma cycle relates to the process of "
5280 @"transcription rather than replication.  It is, however, worth"
5290 @"noting that some texts describe the rolling circle as a sigma"
5300 @"molecule."
5310  FOR J=1 TO 7
5320  @ : NEXT J
5330 LET N=38 : GOSUB 14000
5340 GOSUB 15000
10000 ON ERROR GOTO 10020
10010 CREATE"SCORE"
10020 OPEN\1\"SCORE"
10030 PUT\1\Q,N1,N2,S
10040  FOR N=1 TO 50
10050  PUT\1\O(N)
10060  NEXT N
10070 CLOSE
10080 RUN"PART4"
12000 REM Subroutine to evaluate total number of questions and attempts
12010 REM
12020 REM ********************************************************************
12030 REM
12040 LET T=T+1 : IF T=1 THEN 12060
12050 RETURN
12060 LET Q=Q+1 : RETURN
12070 REM
12080 REM
13000 REM Subroutine for producing sides of box
13010 REM
13020 REM ********************************************************************
13030 REM
13040  FOR I=1 TO 5
13050  GOSUB 13070
13060  PRINT"*"; : PRINT TAB(51);"*" : NEXT I : RETURN
13070 REM Subroutine for spacing
13080 PRINT TAB(20); : RETURN
13090 REM
13100 REM
14000 REM Subroutine for evaluating assessment data
14010 REM
14020 REM ********************************************************************
14040 REM
14050 IF T=1 THEN 14070
14060 LET S=S+0.33333 : LET N2=N2+1 : LET O(N)=0.5 : RETURN
```

```
4070 LET S=S+1 : LET N1=N1+1 : LET O(N)=1 : RETURN
4080 REM
4090 REM
5000 REM Subroutine for generating RETURN box
5010 REM
5020 REM ************************************************************************
5030 REM
5040 @
5050 @TAB(60); : @"############" : @TAB(60);"* RETURN *" : @TAB(60);
5060 @"############"; : INPUT B$
5070 IF B$=""THEN 15140
5080 IF B$="O"THEN 15160
5090 IF B$="S"THEN 15180
5100 IF B$="P"THEN 15120
5110 GOTO 15050
5120 OUT 100,5
5130 GOTO 15140
5140  FOR J=1 TO 7
5150  @ : NEXT J : RETURN
5160 PRINT"Early exit from the program has been requested."
5170 GOTO 20000
5180 GOSUB 16000
5190 GOTO 15050
5200 REM
5210 REM
6000 REM Subroutine for outputing assessment data
6010 REM
6020 REM ************************************************************************
6030 REM
6040  FOR N=1 TO 10
6050  @ : NEXT N
6060 @TAB(5);"*************************************************************************"
6070 @TAB(5);"*"; : @TAB(67);"*"
6080 @USING"     * Total number of questions attempted                =   £££",Q;
6090 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
6100 @USING"     * Number of correct responses on first attempt       =   £££",N1;
6110 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
6120 @USING"     * Number of correct responses on second attempt      =   £££",N2;
6130 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
6140 @USING"     * Percentage score for this session                 =   £££.££",10
6150 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"                                  )*S/
6160 @TAB(5);"*************************************************************************"
6170  FOR N=1 TO 5
6180  @ : NEXT N : RETURN
6190 REM
6200 REM
7000 REM Routine to output microfiche address
7010 REM
7020 REM ************************************************************************
7030 REM
7120 OUT 100,J+128
7130  FOR K=1 TO 40
7140  NEXT K
7150 OUT 100,I
7160 J=I
7170 RETURN
7180 REM
7190 REM
8000 REM Routine to output video segment address
8010 REM
8020 REM ************************************************************************
8030 REM
```

```
18040 OUT 116,255
18050 READ I
18060 OUT 116,I
18070 IF I=255 THEN 18140
18080  FOR I=1 TO 120
18090  NEXT I
18100 OUT 116,255
18110  FOR I=1 TO 120
18120  NEXT I
18130 GOTO 18050
18140  FOR N=1 TO 8
18150  @ : NEXT N
18160 @"                ******************************************"
18170 @"                *                                        *"
18180 @"                *         VIDEO SEGMENT FOLLOWS          *"
18190 @"                *                                        *"
18200 @"                *  Type S/RETURN to stop the programme   *"
18210 @"                *                                        *"
18220 @"                *  To restart, depress the RETURN key    *"
18230 @"                *                                        *"
18240 @"                ******************************************"
18250  FOR N=1 TO 8
18260  @ : NEXT N
18270 INPUT A$
18280 IF A$="S"THEN 18310
18290 IF A$="X"THEN 18450
18300 GOTO 18380
18310 OUT 116,7
18320  FOR I=1 TO 100
18330  NEXT I
18340 OUT 116,255
18350  FOR I=1 TO 100
18360  NEXT I
18370 GOTO 18270
18380 OUT 116,7
18390  FOR I=1 TO 100
18400  NEXT I
18410 OUT 116,255
18420  FOR I=1 TO 100
18430  NEXT I
18440 GOTO 18270
18450 OUT 116,4
18460  FOR I=1 TO 100
18470  NEXT I
18480 OUT 116,255
18490  FOR I=1 TO 100
18500  NEXT I
18510 RETURN
20000 END
```

```
 10 DIM O(50)
 20 OPEN\1\"SCORE"
 30 GET\1\Q,N1,N2,S
 40  FOR N=1 TO 50
 50  GET\1\O(N)
 60  NEXT N
 70 CLOSE
 80 DIM B$(30)
 90 L=27
100  FOR J=1 TO 10
110  @ : NEXT J
120 @TAB(L); : @"**************************"
130 @TAB(L); : @"**                      **"
140 @TAB(L); : @"**   DNA REPLICATION    **"
150 @TAB(L); : @"**                      **"
160 @TAB(L); : @"**        PART 4        **"
170 @TAB(L); : @"**                      **"
180 @TAB(L); : @"**************************"
190  FOR J=1 TO 6
200  @ : NEXT J
220 GOSUB 15000
230  FOR J=1 TO 20
240  @ : NEXT J
250 @"The following frame compares two mechanisms for the replication of"
260 LET I=5 : GOSUB 17000
270 @"double-stranded cyclic DNA...these being the rolling circle model"
280 LET I=65 : GOSUB 17000
290 @"and the modified Cairns' swivel model...to illustrate the major"
300 @"differences."
310  FOR J=1 TO 8
320  @ : NEXT J
330 LET T=0
340 GOSUB 15000
350 GOSUB 12000
360 @ : @
370 @"The frame now shown illustrates the rolling circle model for the"
380 @"replication of circular DNA."
390 LET I=64 : GOSUB 17000
400 @ : @
410 @"What is the name of the enzyme involved in the very first step ?"
420 @ : @ : @
430 GOSUB 13070
440 @"A    DNA polymerase III;" : GOSUB 13070
450 @"B    DNA gyrase;" : GOSUB 13070
460 @"C    protein A;" : GOSUB 13070
470 @"D    DNA ligase;" : GOSUB 13070
480 @"E    cis-A protein."
490  FOR J=1 TO 5
500  @ : NEXT J
510 INPUT B$
520 IF B$="E"THEN 580
530 IF B$="C"THEN 580
540 @ : @
550 @"No, you have not chosen the correct response.....Try the question again."
560 IF T=1 THEN 340
570 GOTO 640
580 @ : @ : @
590 @"Yes, your answer of "; : @TAB(20); : @B$;
600 @" is the correct answer.  You should note, however,"
610 @"that protein A and cis-A protein are one and the same compound."
620  FOR J=1 TO 8
630  @ : NEXT J
```

```
 640 LET N=39 : GOSUB 14000
 650 LET T=0
 660 GOSUB 15000
 670 GOSUB 12000
 680 @ : @ : @
 690 @"Using the same frame, what is the name of the material which 'anchors'"
 700 @"the 5'-end if the (+) strand ?"
 710 @ : @ : @
 720 GOSUB 13070
 730 @"A    protein A;" : GOSUB 13070
 740 @"B    DNA ligase;" : GOSUB 13070
 750 @"C    DNA gyrase," : GOSUB 13070
 760 @"D    DNA polymerase I;" : GOSUB 13070
 770 @"E    DNA polymerase III."
 780  FOR J=1 TO 6
 790  @ : NEXT J
 800 INPUT B$
 810 IF B$="A"THEN 880
 820 @ : @ : @
 830 @"No, your answer is incorrect.  Think carefully about the known function"
 840 @"of each of the proteins in the list and try to arrive at the correct"
 850 @"answer by a process of elimination."
 860 IF T=1 THEN 660
 870 GOTO 930
 880 @ : @ : @
 890 @"Yes, protein A (or cis-A protein) has a dual role in that it acts as a"
 900 @"specific endonuclease and then attaches covalently to the 5' end."
 910  FOR J=1 TO 8
 920  @ : NEXT J
 930 LET N=40 : GOSUB 14000
 940 LET T=0
 950 GOSUB 15000
 960 GOSUB 12000
 970 @ : @ : @
 980 @"Use the list of named compounds supplied below to answer the following"
 990 @"three questions :"
1000 @ : @ : @
1010 @"    1...DNA polymerase I                6...DNA ligase"
1020 @"    2...DNA polymerase III              7...protein A"
1030 @"    3...DNA gyrase                      8...HD-protein"
1040 @"    4...Okazaki fragment                9...catenated DNA"
1050 @"    5...concatenated DNA               10...DNA primers"
1060  FOR J=1 TO 7
1070  @ : NEXT J
1080 @"What is the name of the elongated final structure......"; : INPUT K
1090 @
1100 @"Which enzyme is involved in the synthesis of nascent DNA..."; : INPUT L
1110 @
1120 @"What is the name given to the material indicated as short arrows.";
1130 INPUT M
1140 @ : @ : @
1150 IF K=5 THEN 1170
1160 @"Your answer to the first question is incorrect."
1170 IF L=2 THEN 1190
1180 @ : @"Your answer to the second question is incorrect."
1190 IF M=4 THEN 1230
1200 @ : @"Your answer to the third question is incorrect."
1210 IF T=1 THEN 950
1220 GOTO 1300
1230 IF K+L+M=11 THEN 1250
1240 GOTO 1210
1250 IF M-L=2*(K-M)THEN 1270
```

```
1260 GOTO 1210
1270 @"Yes, well done.  Your answers to all three questions were correct"
1280  FOR J=1 TO 10
1290  @ : NEXT J
1300 LET N=41 : GOSUB 14000
1310 LET T=0
1320 GOSUB 15000
1330 GOSUB 12000
1340 @ : @
1350 LET I=80 : GOSUB 17000
1360 @"The following frame shows a replicating DNA of bacteriophage lambda."
1370 @ : @"What can you deduce from the structure ?"
1380 @ : @ : @
1390 GOSUB 13070
1400 @"A    DNA replicates by rolling circle;" : GOSUB 13070
1410 @"B    DNA replicates by the swivel mechanism;" : GOSUB 13070
1420 @"C    DNA shows branching;" : GOSUB 13070
1430 @"D    DNA is catenated;" : GOSUB 13070
1440 @"E    DNA is intercalated."
1450  FOR J=1 TO 6
1460  @ : NEXT J
1470 INPUT B$
1480 IF B$="A"THEN 1530
1490 @ : @ : @
1500 @"No, your answer is incorrect...consider the line drawing."
1510 IF T=1 THEN 1320
1520 GOTO 1570
1530 @ : @ : @
1540 @"Yes, bacteriophage lambda does replicate as a rolling circle."
1550  FOR J=1 TO 9
1560  @ : NEXT J
1570 LET N=42 : GOSUB 14000
1580 LET T=0
1590 GOSUB 15000
1600 GOSUB 12000
1610 @ : @ : @
1620 LET I=81 : GOSUB 17000
1630 @"The next three electron micrographs which you will study illustrate"
1640 @"the replication of the circular DNA of the cancer-causing animal"
1650 @"virus, SV40."
1660 @ : @ : @
1670 @"Type in the name of the feature labelled as A in the first frame."
1680 @"(Do not use more than 30 characters in your answer)."
1690  FOR J=1 TO 9
1700  @ : NEXT J
1710 @"The name of the feature is....."; : INPUT B$
1720 A=POS(B$,"bubble",0)
1730 B=POS(B$,"Bubble",0)
1740 C=POS(B$,"BUBBLE",0)
1750 D=POS(B$,"eye",0)
1760 E=POS(B$,"Eye",0)
1770 F=POS(B$,"EYE",0)
1780 IF A+B+C+D+E+F>-6 THEN 1840
1790 @ : @ : @
1800 @"On checking your answer, the correct keyword could not be found at any"
1810 @"point.  Try the question one more time."
1820 IF T=1 THEN 1590
1830 GOTO 1980
1840 @ : @ : @
1850 @"Well done....your answer for this particular question was correct." : @
1860 @"Your answer was checked for the presence of a particular set of"
1870 @"keywords.  The correct response was ";
```

```
1880 @TAB(36);
1890 IF A+B+C>-3 THEN 1920
1900 B$="eye."
1910 GOTO 1930
1920 B$="bubble."
1930 @CHR$(27);"dP";
1940 @B$;
1950 @CHR$(27);"d@"
1960  FOR J=1 TO 9
1970  @ : NEXT J
1980 LET N=43 : GOSUB 14000
1990 GOSUB 15000
2000 @ : @
2010 @"The replication bubble that you see at position A grows in a"
2020 @"bidirectional way as we have seen earlier."
2030 @ : @ : @
2040 @"Study the picture carefully, then in a few seconds you will see"
2050 @"the same molecule at a slightly later stage of replication."
2060  FOR J=1 TO 10
2070  @ : NEXT J
2080  FOR J=1 TO 12000.0
2090  NEXT J
2100 J=0
2110 LET I=82 : GOSUB 17000
2120  FOR J=1 TO 1000
2130  NEXT J
2140 LET T=0
2150 GOSUB 15000
2160 GOSUB 12000
2170 @ : @ : @
2180 @"Identify the feature that is now apparent in the structure..."
2190 @ : @ : @ : GOSUB 13070
2200 @"A    catenation;" : GOSUB 13070
2210 @"B    concatenation;" : GOSUB 13070
2220 @"C    intercalation;" : GOSUB 13070
2230 @"D    supercoiling;" : GOSUB 13070
2240 @"E    ligation;" : GOSUB 13070
2250 @"F    hybridisation."
2260  FOR J=1 TO 6
2270  @ : NEXT J
2280 INPUT B$
2290 IF B$="D"THEN 2590
2300 IF B$="A"THEN 2530
2310 IF B$="C"THEN 2470
2320 @ : @ : @
2330 IF B$="B"OR B$="F"THEN 2350
2340 L=8 : GOTO 2360
2350 L=13
2360 @ : @ : @ : @
2370 @"Your answer of ";
2380 @CHR$(27);"dP"; : @TAB(15);
2390 IF B$="B"THEN B$="concatenation"
2400 IF B$="E"THEN B$="ligation"
2410 IF B$="F"THEN B$="hybridisation"
2420 @B$; : @CHR$(27);"d@";
2430 @TAB(15+L); : @"is not the correct response."
2440 @"Try the question one more time"
2450 IF T=1 THEN 2150
2460 GOTO 2740
2470 @ : @ : @
2480 @"Intercalation can certainly lead to this feature....but has no"""
2490 @"direct consequence in the present consideration.  Try the"
```

```
2500 @"question once again with this fact in mind."
2510 IF T=1 THEN 2150
2520 GOTO 2740
2530 @ : @ : @
2540 @"Whilst catenation is a discrete possibility as an interpretation"
2550 @"of this electron micrograph, it is incorrect in the present case."
2560 @ : @"As a clue, consider the lower half of the molecule.."
2570 IF T=1 THEN 2150
2580 GOTO 2740
2590  FOR J=1 TO 6
2600  @ : NEXT J
2610 @"Yes, very well done.  The correct answer was indeed ";
2620 @TAB(52);
2640 @CHR$(27);"dC";
2650 @"supercoiling.";
2660 @CHR$(27);"d@";
2700 @ : @ : @
2710 @"Now have a thought as to why we should get such superhelical twists."
2720  FOR J=1 TO 8
2730  @ : NEXT J
2740 LET N=44 : GOSUB 14000
2750 LET T=0
2760 GOSUB 15000
2770 GOSUB 12000
2780 @ : @
2820 @"Which of the following statements correctly explains the formation"
2830 @"of these superhelical twists ?"
2840 @ : @ : @
2850 GOSUB 13070
2860 @"A     the DNA is constantly melting and"
2870 GOSUB 13070
2880 @"      re-annealing;" : GOSUB 13070
2890 @"B     the negative twists caused by the"
2900 GOSUB 13070
2910 @"      DNA gyrase begin to accumulate;" : GOSUB 13070
2920 @"C     the nascent chains have a tendency"
2930 GOSUB 13070
2940 @"      to over-twist themselves."
2950  FOR J=1 TO 5
2960  @ : NEXT J
2970 INPUT B$
2980 IF B$="B"THEN 3030
2990 @ : @ : @
3000 @"Your answer is incorrect.  Please try the question once again."
3010 IF T=1 THEN 2760
3020 GOTO 3120
3030 @ : @ : @
3040 @"Yes, well done.  This highlights one difference between the mode"
3050 @"of action of DNA gyrase with (i) linear duplex DNA and (ii) cyclic"
3060 @"duplex DNA (closed cyclic).  In the case of the linear (or open"
3070 @"cyclic) DNA the extra twists incorporated by DNA gyrase can be"
3080 @"easily dissipated whereas with a closed cyclic structure this is"
3090 @"not immediately possible."
3100  FOR N=1 TO 7
3110  @ : NEXT N
3120 LET N=45 : GOSUB 14000
3130 LET T=0
3140 GOSUB 15000
3150 GOSUB 12000
3160 @ : @ : @
3170 @"The following frame shows the same molecule towards the end of the"
3180 @"replication cycle.  As you will see, the superhelical region is no"
```

```
3190 @"longer apparent.  Why ?"
3200 @ : @ : @
3210 LET I=83 : GOSUB 17000
3220 GOSUB 13070
3230 @"A    an enzyme, rep protein, acts" : GOSUB 13070
3240 @"     in the opposite sense to the" : GOSUB 13070
3250 @"     DNA gyrase;" : GOSUB 13070
3260 @ : GOSUB 13070
3270 @"B    an endonuclease cleaves the" : GOSUB 13070
3280 @"     DNA which is then later"
3290 GOSUB 13070
3300 @"     sealed by DNA ligase."
3310  FOR J=1 TO 6
3320  @ : NEXT J
3330 INPUT B$
3340 IF B$="B"THEN 3400
3350 @ : @ : @
3360 @"Whilst this suggestion is plausible, there is no experimental"
3370 @"evidence for the presence of such an enzyme."
3380 IF T=1 THEN 3140
3390 GOTO 3450
3400 @ : @ : @
3410 @"Yes, you are quite correct in your belief that an endonuclease "
3420 @"plays such a role in the replication of closed cyclic DNA."
3430  FOR J=1 TO 8
3440  @ : NEXT J
3450 LET N=46 : GOSUB 14000
3460 GOSUB 15000
3470 @ : @
3480 @"The following three frames show other examples of the formation of"
3490 @"such supercoiling in replicating cyclic DNA."
3500 @ : @
3510 LET I=85 : GOSUB 17000
3520 @"As can be seen, the supercoiling is often very tight and this gives"
3530 @"rise to the structures as shown.  Such structures are referred to as"
3540  FOR J=1 TO 3
3550  @ : NEXT J
3560 @TAB(22);
3570 @CHR$(27);"dS";
3580 @" butterfly structures. ";
3590 @CHR$(27);"d@"
3600  FOR J=1 TO 10
3610  @ : NEXT J
3620  FOR J=1 TO 12000.0
3630  NEXT J
3640 J=0
3650 LET I=86 : GOSUB 17000
3660  FOR J=1 TO 12000.0
3670  NEXT J
3680 J=0
3690 LET I=84 : GOSUB 17000
3700 LET T=0
3710 GOSUB 15000
3720 GOSUB 12000
3730 @ : @
3740 @"What is being depicted schematically in the frame now showing ?"
3750 @ : @ : @
3760 LET I=88 : GOSUB 17000
3770 GOSUB 13070
3780 @"A    formation of apurinic acid;" : GOSUB 13070
3790 @"B    uracil excision;" : GOSUB 13070
3800 @"C    primer excision;" : GOSUB 13070
```

```
3810 @"D    thymine dimer formation;" : GOSUB 13070
3820 @"E    photoreactivation;" : GOSUB 13070
3830 @"F    branch formation."
3840  FOR J=1 TO 6
3850  @ : NEXT J
3860 INPUT B$
3870 IF B$="C"THEN 4000
3880 IF B$="B"THEN 3940
3890 @ : @ : @
3900 @"The question is really not that difficult !!!   Look carefully at the"
3910 @"the top line of the figure then re-try the question."
3920 IF T=1 THEN 3710
3930 GOTO 4060
3940 @ : @ : @
3950 @"At first sight this may look like uracil excision.....mainly because"
3960 @"there are uracil residues present !   However, look more carefully "
3970 @"at the top line of the figure then re-try the question."
3980 IF T=1 THEN 3710
3990 GOTO 4060
4000 @ : @ : @
4010 @"Well done, the clue to answering this question came from the"
4020 @"observation that the sugar moieties on the material excised"
4030 @"were ribose sugars rather than deoxyribose."
4040  FOR J=1 TO 7
4050  @ : NEXT J
4060 LET N=47 : GOSUB 14000
4070 LET T=0
4080 GOSUB 15000
4090 GOSUB 12000
4100 @ : @
4110 @"Using the table of enzymes shown below,"
4120 @ : @
4130 @"    1...DNA polymerase I                6...DNA ligase"
4140 @"    2...DNA polymerase II               7...RNA polymerase"
4150 @"    3...DNA polymerase III              8...unwinding enzyme"
4160 @"    4...DNA gyrase                      9...ribonuclease"
4170 @"    5...specific endonuclease          10...uracil glycosidase"
4180 @ : @ : @
4190 @"answer the following questions :"
4200  FOR J=1 TO 6
4210  @ : NEXT J
4220 @"Which enzyme carries out step 1.....";  : INPUT K
4230 @
4240 @"Which enzyme carries out step 2.....";  : INPUT L
4250 @
4260 @"Which additional enzyme is required for repair ...";  : INPUT M
4270 IF K=5 AND L=1 AND M=6 THEN 4330
4280 IF K<>5 THEN@"Incorrect answer to the first part."
4290 IF L<>1 THEN@"Incorrect answer to the second part."
4300 IF M<>6 THEN@"Incorrect answer to the third part."
4310 IF T=1 THEN 4080
4320 GOTO 4370
4330 @ : @ : @
4340 @"Well done, you were correct in all three parts of the question."
4350  FOR J=1 TO 9
4360  @ : NEXT J
4370 LET N=48 : GOSUB 14000
4380 LET T=0
4390 GOSUB 15000
4400 GOSUB 12000
4410 @ : @ : @
4420 @"The frame now showing illustrates the repair mechanism for DNA"
```

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4430 @"damaged by uv-irradiation."
4440 @ : @
4450 LET I=89 : GOSUB 17000
4460 @"What is the nature of the dimer ?"
4470 @ : @ : @ : @ : GOSUB 13070
4480 @"A    thymine;" : GOSUB 13070
4490 @"B    adenine;" : GOSUB 13070
4500 @"C    cytosine;" : GOSUB 13070
4510 @"D    uracil;" : GOSUB 13070
4520 @"E    guanine;" : GOSUB 13070
4530 @"F    purine;" : GOSUB 13070
4540 @"G    pyrimidine;" : GOSUB 13070
4550  FOR J=1 TO 5
4560  @ : NEXT J
4570 INPUT B$
4580 IF B$="G"THEN 4700
4590 IF B$="A"OR B$="C"THEN 4650
4600 @ : @ : @
4610 @"No, your choice of answer is incorrect in this case.  Try the"
4620 @"question one more time."
4630 IF T=1 THEN 4390
4640 GOTO 4750
4650 @ : @ : @
4660 @"Almost, but not quite.....think of your lecture notes on this"
4670 @"topic then try again."
4680 IF T=1 THEN 4390
4690 GOTO 4750
4700 @ : @ : @
4710 @"Yes, the more general answer of pyrimidine is correct although we"
4720 @"see reference to 'thymine dimer' much more frequently."
4730  FOR J=1 TO 9
4740  @ : NEXT J
4750 LET N=49 : GOSUB 14000
4760 LET T=0
4770 GOSUB 15000
4780 GOSUB 12000
4790 @ : @ : @
4800 @"In which direction does the exonuclease in step 3 operate ?"
4810 @ : @ : @ : GOSUB 13070
4820 @"A    3' -----> 5' ;" : GOSUB 13070
4830 @"B    5' -----> 3' ;" : GOSUB 13070
4840 @"C    both."
4850  FOR J=1 TO 8
4860  @ : NEXT J
4870 INPUT B$
4880 IF B$="B"THEN 4940
4890 @ : @ : @ : @
4900 @"Considering that the figure has the information, your attempt is"
4910 @"really pretty poor.  Take care, then try again."
4920 IF T=1 THEN 4770
4930 GOTO 4990
4940 @ : @ : @ : @
4950 @"Yes, your answer is correct...although the question was not too"
4960 @"difficult since the information is printed on the figure !"
4970  FOR J=1 TO 7
4980  @ : NEXT J
4990 LET N=50 : GOSUB 14000
5000 GOSUB 15000
5010 @ : @ : @ : @
5020 LET I=90 : GOSUB 17000
5030 @"The cut-and-patch mode of DNA repair is summarized in the figure"
5040 @"now showing.  In your own time, you should compare the mechanism"
```

```
 5050 @"with some of the other repair mechanisms that operate in vivo."
 5060  FOR J=1 TO 9
 5070  @ : NEXT J
 5080 GOSUB 15000
 5090 OUT 100,91
10000 ON ERROR GOTO 10020
10010 CREATE"SCORE"
10020 OPEN\1\"SCORE"
10030 PUT\1\Q,N1,N2,S
10040  FOR N=1 TO 50
10050  PUT\1\O(N)
10060  NEXT N
10070 CLOSE
10080 RUN"PART8"
12000 REM Subroutine to evaluate total number of questions and attempts
12010 REM
12020 REM ********************************************************************
12030 REM
12040 LET T=T+1 : IF T=1 THEN 12060
12050 RETURN
12060 LET Q=Q+1 : RETURN
12070 REM
12080 REM
13000 REM Subroutine for producing sides of box
13010 REM
13020 REM ********************************************************************
13030 REM
13040  FOR I=1 TO 5
13050  GOSUB 13070
13060  PRINT"*"; : PRINT TAB(51);"*" : NEXT I : RETURN
13070 REM Subroutine for spacing
13080 PRINT TAB(20); : RETURN
13090 REM
13100 REM
14000 REM Subroutine for evaluating assessment data
14010 REM
14020 REM ********************************************************************
14040 REM
14050 IF T=1 THEN 14070
14060 LET S=S+0.33333 : LET N2=N2+1 : LET O(N)=0.5 : RETURN
14070 LET S=S+1 : LET N1=N1+1 : LET O(N)=1 : RETURN
14080 REM
14090 REM
15000 REM Subroutine for generating RETURN box
15010 REM
15020 REM ********************************************************************
15030 REM
15040 @
15050 @TAB(60); : @"***********" : @TAB(60);"* RETURN *" : @TAB(60);
15060 @"***********"; : INPUT B$
15070 IF B$=""THEN 15140
15080 IF B$="O"THEN 15160
15090 IF B$="S"THEN 15180
15100 IF B$="P"THEN 15120
15110 GOTO 15050
15120 OUT 100,5
15130 GOTO 15140
15140  FOR J=1 TO 7
15150  @ : NEXT J : RETURN
15160 PRINT"Early exit from the program has been requested."
15170 GOTO 20000
15180 GOSUB 16000
```

```
15190 GOTO 15050
15200 REM
15210 REM
16000 REM Subroutine for outputing assessment data
16010 REM
16020 REM ************************************************************************
16030 REM
16040  FOR N=1 TO 10
16050  @ : NEXT N
16060 @TAB(5);"************************************************************************"
16070 @TAB(5);"*"; : @TAB(67);"*"
16080 @USING"     * Total number of questions attempted                =   £££",Q;
16090 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
16100 @USING"     * Number of correct responses on first attempt       =   £££",N1;
16110 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
16120 @USING"     * Number of correct responses on second attempt      =   £££",N2;
16130 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"
16140 @USING"     * Percentage score for this session                 =   £££.££",1
16150 @TAB(67);"*" : @TAB(5);"*"; : @TAB(67);"*"                              )*5/
16160 @TAB(5);"************************************************************************"
16170  FOR N=1 TO 5
16180  @ : NEXT N : RETURN
16190 REM
16200 REM
17000 REM Routine to output microfiche address
17010 REM
17020 REM ************************************************************************
17030 REM
17120 OUT 100,J+128
17130  FOR K=1 TO 40
17140  NEXT K
17150 OUT 100,I
17160 J=I
17170 RETURN
17180 REM
17190 REM
18000 REM Routine to output video segment address
18010 REM
18020 REM ************************************************************************
18030 REM
18040 OUT 116,255
18050 READ I
18060 OUT 116,I
18070 IF I=255 THEN 18140
18080  FOR I=1 TO 120
18090  NEXT I
18100 OUT 116,255
18110  FOR I=1 TO 120
18120  NEXT I
18130 GOTO 18050
18140  FOR N=1 TO 8
18150  @ : NEXT N
18160 @"              ******************************************"
18170 @"              *                                        *"
18180 @"              *         VIDEO SEGMENT FOLLOWS          *"
18190 @"              *                                        *"
18200 @"              *  Type S/RETURN to stop the programme   *"
18210 @"              *                                        *"
18220 @"              *  To restart, depress the RETURN key    *"
18230 @"              *                                        *"
18240 @"              ******************************************"
18250  FOR N=1 TO 8
```

```
18260  @ : NEXT N
18270 INPUT A$
18280 IF A$="S"THEN 18310
18290 IF A$="X"THEN 18450
18300 GOTO 18380
18310 OUT 116,7
18320  FOR I=1 TO 100
18330  NEXT I
18340 OUT 116,255
18350  FOR I=1 TO 100
18360  NEXT I
18370 GOTO 18270
18380 OUT 116,7
18390  FOR I=1 TO 100
18400  NEXT I
18410 OUT 116,255
18420  FOR I=1 TO 100
18430  NEXT I
18440 GOTO 18270
18450 OUT 116,4
18460  FOR I=1 TO 100
18470  NEXT I
18480 OUT 116,255
18490  FOR I=1 TO 100
18500  NEXT I
18510 RETURN
20000 END
```

```
 20 REM ************************************************************************
 30 REM
 50 REM The function of this part of the program is to transfer current
 60 REM values for all the scores etc for the session to Part 9 where
 70 REM they are further processed in terms of learning objectives.
 80 REM
 90 REM ************************************************************************
100 REM
110 DIM O(50)
130 OPEN\1\"SCORE"
140 GET\1\Q,N1,N2,S
150  FOR N=1 TO 50
160  GET\1\O(N)
170  NEXT N
180 CLOSE
280 ON ERROR GOTO 300
290 CREATE"SCORE"
300 OPEN\1\"SCORE"
320 PUT\1\Q,N1,N2,S
330  FOR N=1 TO 50
340  PUT\1\O(N)
350  NEXT N
370 CLOSE
380 REM ************************************************************************
390 REM
400 REM The function of this part of the program is to finally manage
420 REM all of the various audio-visual devices.  Thus the microfiche
430 REM is ejected, the audio and video-tapes are rewound etc.
440 REM
450 REM ************************************************************************
460 LET I=1 : GOSUB 500
470 RUN"PART9"
480  FOR J=1 TO 3
490  @ : NEXT J : STOP
500 REM Routine to output microfiche address
510 OUT 100,J+128
520  FOR K=1 TO 40
530  NEXT K
540 OUT 100,I
550 J=I
560 RETURN
570 END
```

PART 9

```
 10 DIM O(50)
 20 DIM U$(25) : DIM C$(25)
 30 OPEN\1\"SCORE"
 40 GET\1\Q,N1,N2,S
 50  FOR N=1 TO 50
 60  GET\1\O(N)
 70  NEXT N
 90 CLOSE
100 INPUT"Type in your name.......",U$
110 @ : @
120 INPUT"Type in your class......",C$
130 @ : @ : @
140 @CHR$(23)
150 @ : @ : @ : @
160 @"   ********************************************************************************"
170 @"   *                                                                              *"
180 @USING"   *       Student name.......£££££££££££££££££££££££",U$;
190 @TAB(71);"*"
200 @TAB(3);"*"; : @TAB(71);"*"
210 @TAB(3);"*"; : @TAB(71);"*"
220 @USING"   *       Class..............£££££££££££££££££££££££",C$;
230 @TAB(71);"*"
240 @"   *                                                                              *"
250 @"   ********************************************************************************"
260 @ : @ : @
270 @"   ********************************************************************************"
280 @TAB(3);"*"; : @TAB(71);"*"
290 @"   *       The following represents those learning objectives which     *"
300 @"   *       you have clearly mastered :                                  *"
310 @TAB(3);"*"; : @TAB(71);"*"
320 @TAB(3);"*"; : @TAB(71);"*"
330  FOR N=1 TO 50
340  IF O(N)>0.8 THEN 360
350  GOTO 390
360  GOSUB 1060
380  @TAB(3);"*"; : @TAB(71);"*"
390  NEXT N
400 @TAB(3);"*"; : @TAB(71);"*"
410 @"   ********************************************************************************"
420 @ : @ : @
450 @"   ********************************************************************************"
460 @TAB(3);"*"; : @TAB(71);"*"
470 @"   *       The following represents those learning objectives which     *"
480 @"   *       you have struggled with in part :                            *"
490 @TAB(3);"*"; : @TAB(71);"*"
500 @TAB(3);"*"; : @TAB(71);"*"
510  FOR N=1 TO 25
520  IF O(N)<0.8 THEN 540
530  GOTO 590
540  IF O(N)>=0.5 THEN 560
550  GOTO 590
560  GOSUB 1060
580  @TAB(3);"*"; : @TAB(71);"*"
590  NEXT N
600 @TAB(3);"*"; : @TAB(71);"*"
610 @"   ********************************************************************************"
620 @ : @ : @
630 @"   ********************************************************************************"
640 @TAB(3);"*"; : @TAB(71);"*"
650 @"   *       The following represents those learning objectives which     *"
660 @"   *       you are very clearly finding difficult to grasp :            *"
670 @TAB(3);"*"; : @TAB(71);"*"
```

```
680 @TAB(3);"*"; : @TAB(71);"*"
690  FOR N=1 TO 25
700  IF O(N)<0.5 THEN 720
710  GOTO 750
720  GOSUB 1060
740  @TAB(3);"*"; : @TAB(71);"*"
750  NEXT N
760 @TAB(3);"*"; : @TAB(71);"*"
770 @"   ***************************************************************************"
780 @ : @ : @
790 @"   ***************************************************************************"
800 @TAB(3);"*"; : @TAB(71);"*"
810 @USING"   *       Total number of questions attempted              =   £££",Q
820 @TAB(71);"*"
830 @TAB(3);"*"; : @TAB(71);"*"
840 @USING"   *       Number of correct responses on first attempt     =   £££",N
850 @TAB(71);"*"
860 @TAB(3);"*"; : @TAB(71);"*"
870 @USING"   *       Number of correct responses on second attempt    =   £££",N
880 @TAB(71);"*"                                                              2
890 @TAB(3);"*"; : @TAB(71);"*"
900 LET B=100*S/Q
910 @USING"   *       Percentage score for the assessment session      =   £££.££
920 @TAB(71);"*"                                                              ",B,
930 @TAB(3);"*"; : @TAB(71);"*"
940 @TAB(3);"*"; : @TAB(71);"*"
950 @"   ***************************************************************************"
970 @ : @ : @
980 @CHR$(20) : LET Q=N1=N2=S=0
990  FOR J=1 TO 50
1000  LET O(J)=0
1010  NEXT J
1020 STOP
1060 REM Subroutine to relate learning objective to question number
1070 IF N=1 THEN 1590
1080 IF N=2 THEN 1620
1090 IF N=3 THEN 1670
1100 IF N=4 THEN 1720
1110 IF N=5 THEN 1750
1120 IF N=6 THEN 1800
1130 IF N=7 THEN 1850
1140 IF N=8 THEN 1900
1150 IF N=9 THEN 1970
1160 IF N=10 THEN 2020
1170 IF N=11 THEN 2090
1180 IF N=12 THEN 2160
1190 IF N=13 THEN 2230
1200 IF N=14 THEN 2280
1210 IF N=15 THEN 2330
1220 IF N=16 THEN 2380
1230 IF N=17 THEN 2430
1240 IF N=18 THEN 2480
1250 IF N=19 THEN 2530
1260 IF N=20 THEN 2580
1270 IF N=21 THEN 2630
1280 IF N=22 THEN 2690
1290 IF N=23 THEN 2740
1300 IF N=24 THEN 2790
1310 IF N=25 THEN 2840
1320 IF N=26 THEN 2930
1330 IF N=27 THEN 2980
1350 IF N=28 THEN 3030
```

```
1360 IF N=29 THEN 3080
1370 IF N=30 THEN 3150
1380 IF N=31 THEN 3200
1390 IF N=32 THEN 3250
1400 IF N=33 THEN 3300
1410 IF N=34 THEN 3350
1420 IF N=35 THEN 3400
1430 IF N=36 THEN 3450
1440 IF N=37 THEN 3500
1450 IF N=38 THEN 3550
1460 IF N=39 THEN 3600
1470 IF N=40 THEN 3650
1480 IF N=41 THEN 3700
1490 IF N=42 THEN 3750
1500 IF N=43 THEN 3800
1510 IF N=44 THEN 3850
1520 IF N=45 THEN 3920
1530 IF N=46 THEN 3950
1540 IF N=47 THEN 4020
1550 IF N=48 THEN 4070
1560 IF N=49 THEN 4120
1570 IF N=50 THEN 4170
1590 @"    *          - identifies nucleic acid within an electron micrograph";
1600 @TAB(71);"*"
1610 RETURN
1620 @"    *          - distinguishes between linear and cyclic DNA as seen";
1630 @TAB(71);"*"
1640 @"    *            in electron micrographs";
1650 @TAB(71);"*"
1660 RETURN
1670 @"    *          - distinguishes between the deep and narrow grooves in";
1680 @TAB(71);"*"
1690 @"    *            duplex DNA";
1700 @TAB(71);"*"
1710 RETURN
1720 @"    *          - distinguishes between A-form and B-form DNA";
1730 @TAB(71);"*"
1740 RETURN
1750 @"    *          - evaluates the dimension of the deep groove of DNA";
1760 @TAB(71);"*"
1770 @"    *            from data supplied";
1780 @TAB(71);"*"
1790 RETURN
1800 @"    *          - evaluates the dimension of the narrow groove of DNA";
1810 @TAB(71);"*"
1820 @"    *            from data supplied";
1830 @TAB(71);"*"
1840 RETURN
1850 @"    *          - identifies the characteristic diffraction pattern";
1860 @TAB(71);"*"
1870 @"    *            derived from a helix";
1880 @TAB(71);"*"
1890 RETURN
1900 @"    *          - distinguishes between those spots on an X-ray";
1910 @TAB(71);"*"
1920 @"    *            diffraction pattern corresponding to low and high";
1930 @TAB(71);"*"
1940 @"    *            resolution experimental data";
1950 @TAB(71);"*"
1960 RETURN
1970 @"    *          - states the number of base pairs found in B-form";
1980 @TAB(71);"*"
```

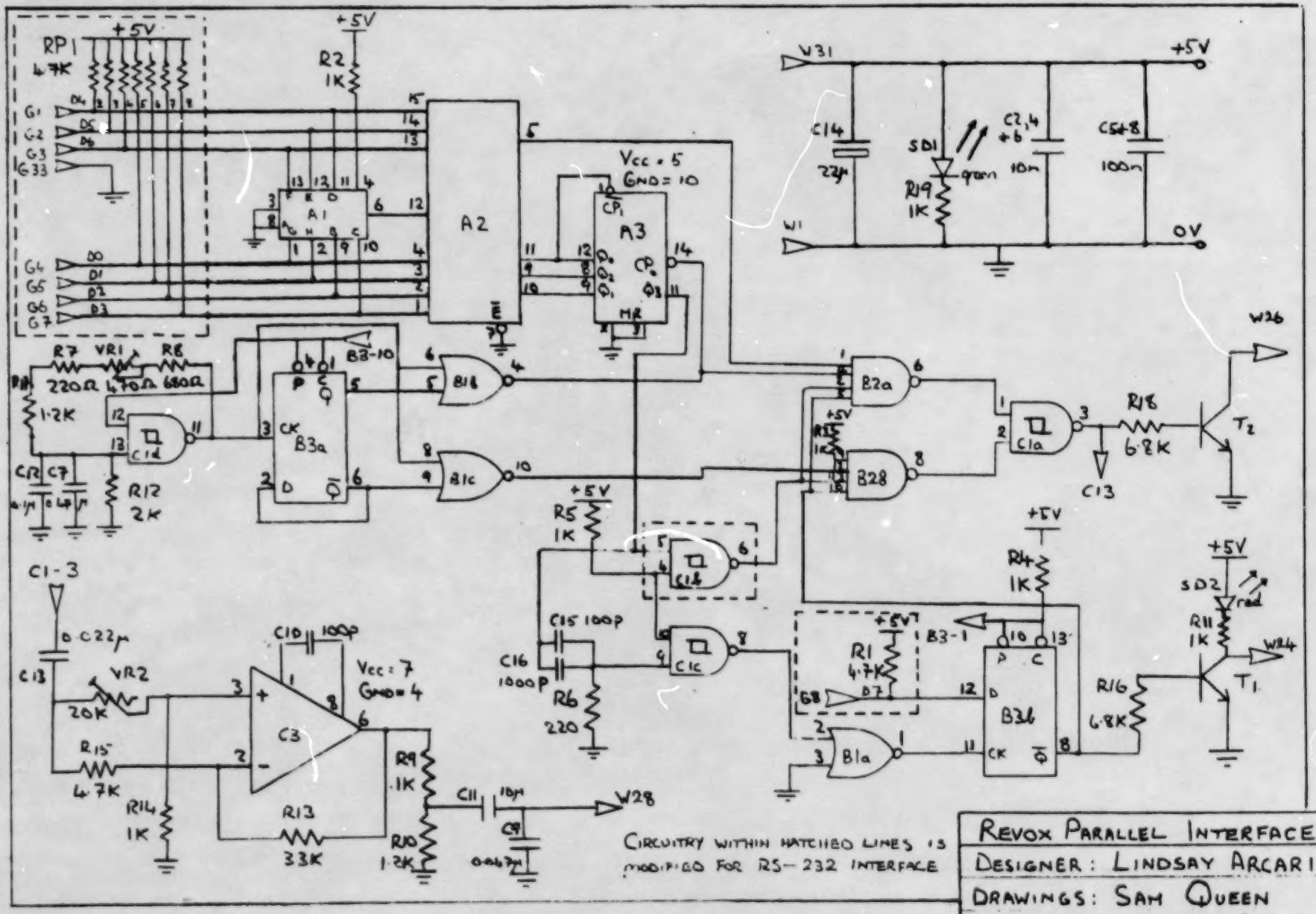
```
1990 @"   *          DNA";
2000 @TAB(71);"*"
2010 RETURN
2020 @"   *        - calculates the length of a DNA duplex given the";
2030 @TAB(71);"*"
2040 @"   *          molecular weight of the DNA and the molecular";
2050 @TAB(71);"*"
2060 @"   *          weight for an 'average' base pair";
2070 @TAB(71);"*"
2080 RETURN
2090 @"   *        - identifies the relationship between the viscosity";
2100 @TAB(71);"*"
2110 @"   *          of a solution of DNA and the physical structure of";
2120 @TAB(71);"*"
2130 @"   *          the DNA molecule";
2140 @TAB(71);"*"
2150 RETURN
2160 @"   *        - illustrates the significance of intermolecular";
2170 @TAB(71);"*"
2180 @"   *          base pairing in single-stranded RNA to the";
2190 @TAB(71);"*"
2200 @"   *          physical properties of the RNA molecule";
2210 @TAB(71);"*"
2220 RETURN
2230 @"   *        - distinguishes between a wide variety of tertiary";
2240 @TAB(71);"*"
2250 @"   *          structures for DNA";
2260 @TAB(71);"*"
2270 RETURN
2280 @"   *        - distinguishes between supercoiled DNA and relaxed";
2290 @TAB(71);"*"
2300 @"   *          cyclic DNA";
2310 @TAB(71);"*"
2320 RETURN
2330 @"   *        - evaluates the contour length for a given DNA";
2340 @TAB(71);"*"
2350 @"   *          molecule from EM data";
2360 @TAB(71);"*"
2370 RETURN
2380 @"   *        - identifies the unique tertiary structure of DNA";
2390 @TAB(71);"*"
2400 @"   *          isolated from mitochondria and chloroplasts";
2410 @TAB(71);"*"
2420 RETURN
2430 @"   *        - states that DNA replication occurs by a semi-";
2440 @TAB(71);"*"
2450 @"   *          conservative mechanism";
2460 @TAB(71);"*"
2470 RETURN
2480 @"   *        - distinguishes between semi-conservative replication";
2490 @TAB(71);"*"
2500 @"   *          and other plausible modes of replication";
2510 @TAB(71);"*"
2520 RETURN
2530 @"   *        - describes the key features of the Meselson and";
2540 @TAB(71);"*"
2550 @"   *          Stahl experiment";
2560 @TAB(71);"*"
2570 RETURN
2580 @"   *        - describes the procedure and rationale of density";
2590 @TAB(71);"*"
2600 @"   *          gradient centrifugation using CsCl";
```

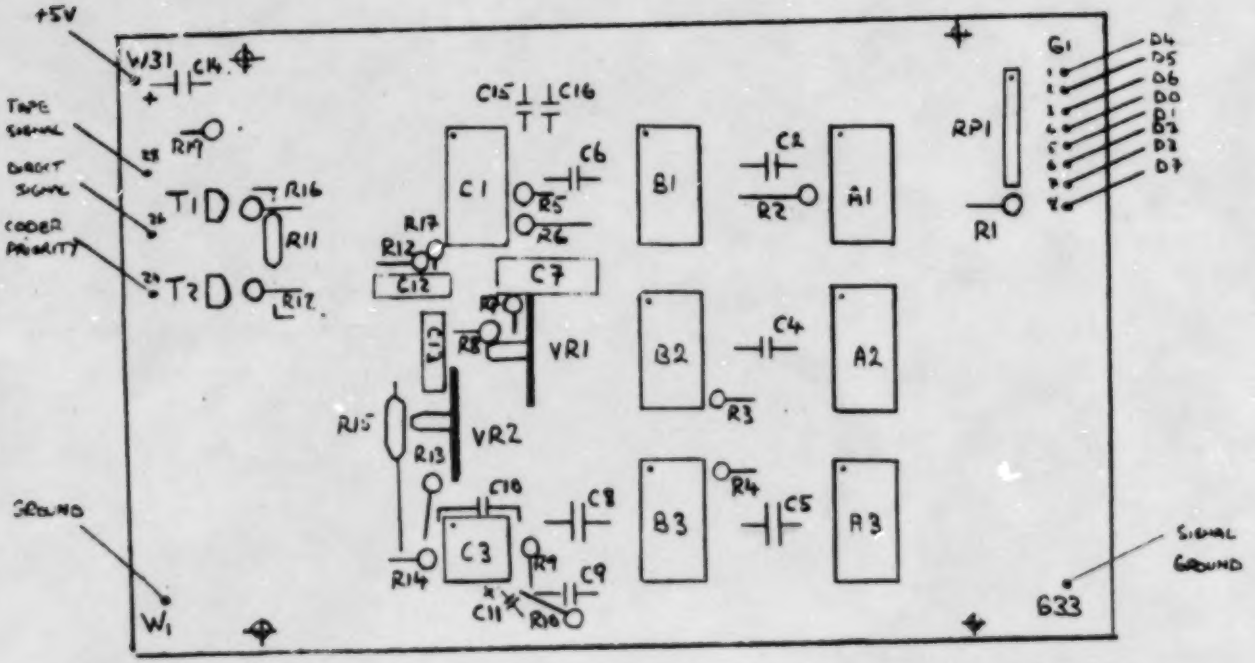
```
2610 @TAB(71);"**"
2620 RETURN
2630 @"   *       - states the value of the characteristic absorption";
2640 @TAB(71);"**"
2650 @"   *         maximum for DNA";
2660 @TAB(71);"**"
2670 RETURN
2690 @"   *       - distinguishes between the terms first generation and";
2700 @TAB(71);"**"
2710 @"   *         second generation as applied to replication";
2720 @TAB(71);"**"
2730 RETURN
2740 @"   *       - outlines the nature of the banding pattern obtained";
2750 @TAB(71);"**"
2760 @"   *         in the Meselson and Stahl experiment";
2770 @TAB(71);"**"
2780 RETURN
2790 @"   *       - predicts the sequence of a DNA strand which is";
2800 @TAB(71);"**"
2810 @"   *         complementary to a given segment of DNA";
2820 @TAB(71);"**"
2830 RETURN
2840 @"   *       - describes the three peculiarities of the product";
2850 @TAB(71);"**"
2860 @"   *         obtained on incubating native double-stranded DNA";
2870 @TAB(71);"**"
2880 @"   *         with DNA dependent DNA polymerase I";
2890 @TAB(71);"**"
2900 RETURN
2930 @"   *       - describes the experimental evidence against the";
2940 @TAB(71);"**"
2950 @"   *         replicase role for DNA polymerase I";
2960 @TAB(71);"**"
2970 RETURN
2980 @"   *       - identifies the functional role for Okazaki";
2990 @TAB(71);"**"
3000 @"   *         fragments during replication";
3010 @TAB(71);"**"
3020 RETURN
3030 @"   *       - distinguishes between discontinuous and";
3040 @TAB(71);"**"
3050 @"   *         continuous DNA strand synthesis";
3060 @TAB(71);"**"
3070 RETURN
3080 @"   *       - describes and distinguishes the functional";
3090 @TAB(71);"**"
3100 @"   *         roles for the various enzymes/proteins which";
3110 @TAB(71);"**"
3120 @"   *         participate in DNA replication";
3130 @TAB(71);"**"
3140 RETURN
3150 @"   *       - describes the experimental evidence for the";
3160 @TAB(71);"**"
3170 @"   *         view that DNA synthesis occurs bidirectionally";
3180 @TAB(71);"**"
3190 RETURN
3200 @"   *       - identifies replication bubbles in electron";
3210 @TAB(71);"**"
3220 @"   *         micrographs";
3230 @TAB(71);"**"
3240 RETURN
3250 @"   *       - describes the role of multiple initiation sites";
```

```
3260 @TAB(71);"**"
3270 @"   *        during replication";
3280 @TAB(71);"**"
3290 RETURN
3300 @"   *      - distinguishes replication bubbles from other";
3310 @TAB(71);"**"
3320 @"   *        DNA tertiary structures";
3330 @TAB(71);"**"
3340 RETURN
3350 @"   *      - identifies multiple replication bubbles in an";
3360 @TAB(71);"**"
3370 @"   *        electron micrograph";
3380 @TAB(71);"**"
3390 RETURN
3400 @"   *      - states alternative explanations for the";
3410 @TAB(71);"**"
3420 @"   *        DNA";
3430 @TAB(71);"**"
3440 RETURN
3450 @"   *      - distinguishes a replication bubble from a";
3460 @TAB(71);"**"
3470 @"   *        appearance of loops in electron micrographs";
3480 @TAB(71);"**"
3490 RETURN
3500 @"   *      - identifies replicating cyclic DNA in";
3510 @TAB(71);"**"
3520 @"   *        electron micrographs";
3530 @TAB(71);"**"
3540 RETURN
3550 @"   *      - states the different models for the";
3560 @TAB(71);"**"
3570 @"   *        replication of double-stranded cyclic DNA";
3580 @TAB(71);"**"
3590 RETURN
3600 @"   *      - states that cis-A protein acts as a specific";
3610 @TAB(71);"**"
3620 @"   *        endonuclease in DNA replication";
3630 @TAB(71);"**"
3640 RETURN
3650 @"   *      - describes the dual functional role for cis-A";
3660 @TAB(71);"**"
3670 @"   *        protein";
3680 @TAB(71);"**"
3690 RETURN
3700 @"   *      - states the key features of the rolling";
3710 @TAB(71);"**"
3720 @"   *       circle model for DNA replication";
3730 @TAB(71);"**"
3740 RETURN
3750 @"   *      - identifies a DNA molecules exhibiting";
3760 @TAB(71);"**"
3770 @"   *        rolling circle replication";
3780 @TAB(71);"**"
3790 RETURN
3800 @"   *      - outlines the steps involved in the replication";
3810 @TAB(71);"**"
3820 @"   *        of a closed-cyclic DNA duplex";
3830 @TAB(71);"**"
3840 RETURN
3850 @"   *      - decribes the origin anf fate of superhelical";
3860 @TAB(71);"**"
3870 @"   *        twists during replication of closed-cyclic";
```

```
3880 @TAB(71);"**"
3890 @"   *          double-stranded DNA";
3900 @TAB(71);"**"
3910 RETURN
3920 @"   *       - describes the mode of action of DNA gyrase";
3930 @TAB(71);"**"
3940 RETURN
3950 @"   *       - describes the way in which the supercoiling";
3960 @TAB(71);"**"
3970 @"   *          in a replicating cyclic DNA duplex can be";
3980 @TAB(71);"**"
3990 @"   *          dissipated";
4000 @TAB(71);"**"
4010 RETURN
4020 @"   *       - distinguishes between uracil excision and";
4030 @TAB(71);"**"
4040 @"   *          primer excision";
4050 @TAB(71);"**"
4060 RETURN
4070 @"   *       - outlines the mode of action of the enzymes";
4080 @TAB(71);"**"
4090 @"   *          that take part in butterfly replication";
4100 @TAB(71);"**"
4110 RETURN
4120 @"   *       - outlines the steps in the repair process";
4130 @TAB(71);"**"
4140 @"   *          for uv-irradiation damaged DNA";
4150 @TAB(71);"**"
4160 RETURN
4170 @"   *       - describes the mechanisms for DNA repair";
4180 @TAB(71);"**"
4190 RETURN
9999 END
```

Revox Microfiche/Cromemco System 3


RP1
4.7K
+5V
R2
1K
A1
A2
A3
Vcc = 5
GND = 10
W31
W1
C14
22µ
SD1
grn
R19
1K
C2,4
+6
10n
C5-8
100n
R7
VR1
R8
220Ω
470Ω
680Ω
1.2K
R12
2K
C12
C7
B3-10
B3a
B1a
B1b
B1c
B2a
B2b
C1a
C1b
C1c
C1d
R18
6.8K
T2
W26
C13
R5
1K
C15 100P
C16
1000P
R6
220
R4
1K
SD2
red
R11
1K
W24
T1
R16
6.8K
B3-1
R1
4.7K
B3b
C1-3
C13
0.22µ
VR2
20K
R15
4.7K
R14
1K
C10
100P
Vcc = 7
GND = 4
C3
R13
33K
R9
1K
R10
1.2K
C11
10µ
C9
0.047µ
W28
CIRCUITRY WITHIN HATCHED LINES IS MODIFIED FOR RS-232 INTERFACE
REVOX PARALLEL INTERFACE
DESIGNER: LINDSAY ARCARI
DRAWINGS: SAM QUEEN
DEC 1980 DEPT OF PHYSICS



G-2

VR1	470Ω	R13	33KΩ	RP1	4·7KΩ Pack	C9	0·047μF
VR2	20KΩ	R16+18	6·8KΩ	R1+15	4·7KΩ	C10+15	100pF
SD1+2	0·2" L.E.D.	T1+T2	BC109 or BC237	R2,3,4,5,9,11,14,17,19 (3)(4)	1KΩ	C11	10μF
				R6+7 (1)	220Ω	C12	0·1μF
				R8 (2)	680Ω	C13	0·022μF
				R10	1·2KΩ	C14	22μF
				R12	2KΩ	C16	1000pF

A1	74180
A2	74LS151
A3	74LS93
B1	74LS02
B2	74LS20
B3	74LS74
C1	74LS132
C3	LM301
C2, 4+6	10nF
C5+8	100nF
C7	0·47μF

NOTES

(1) R7 may be optional
(2) 470Ω or 390Ω
(3) or 1·2KΩ for R17
(4) or 220Ω for R11+19

Sony RX-353/Cromemco System 3

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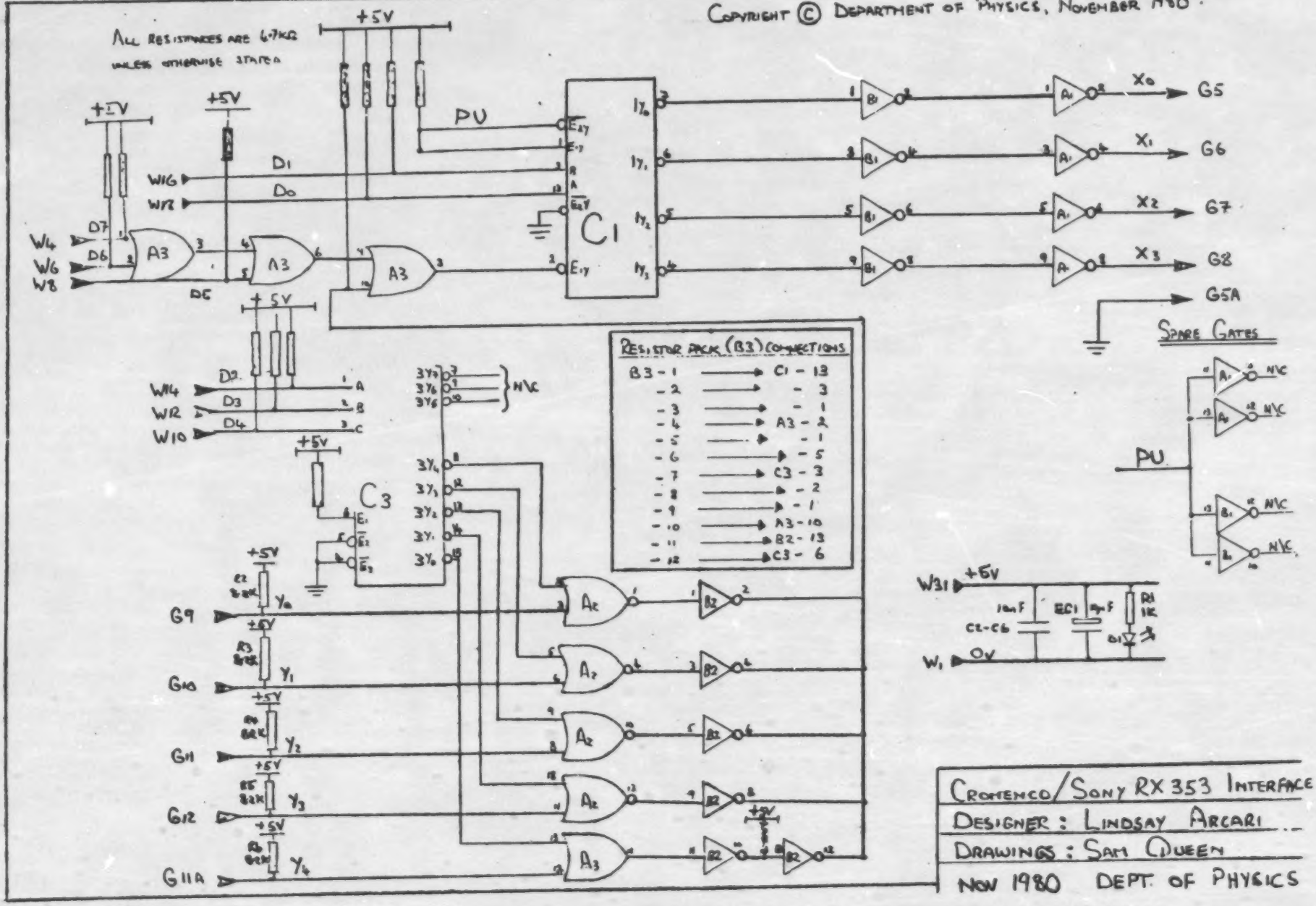
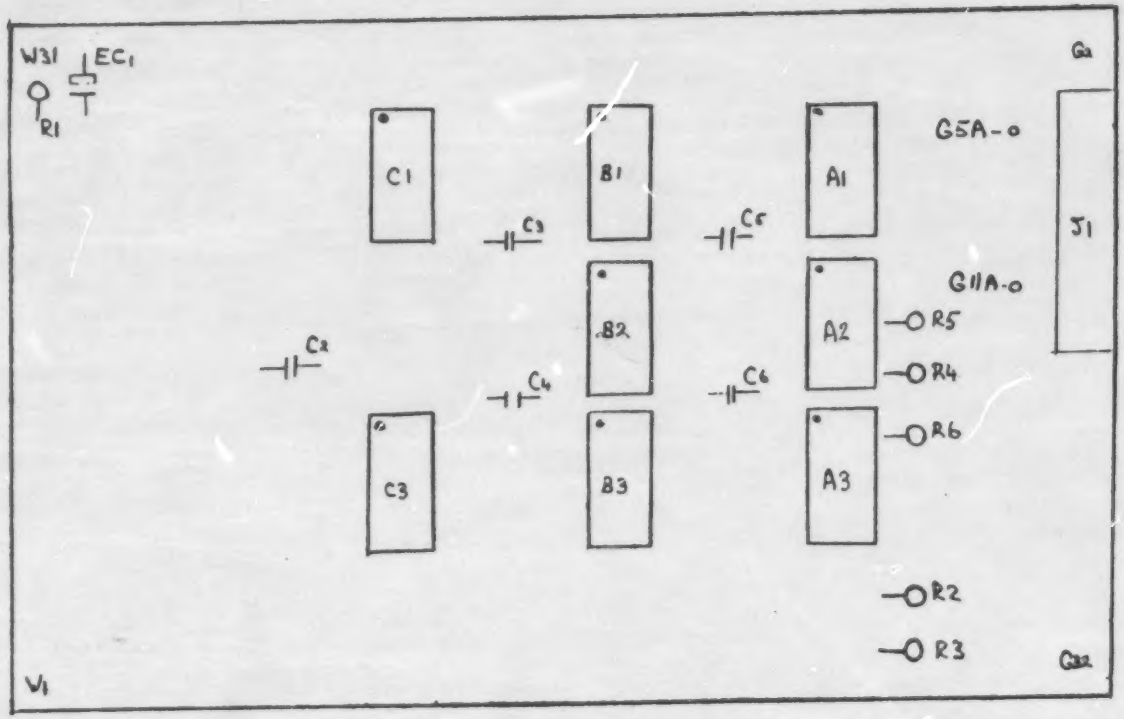


CROYDENCO/SONY RX 353 INTERFACE
DESIGNER: LINDSAY ARCARI
DRAWINGS: SAM QUEEN
NOV 1980 DEPT. OF PHYSICS



G-4

G2 - G32 ARE GOLD NUMBERS 2-32
W1 - W31 ARE WHITE NUMBERS 1-31

J1 — 15 WAY P.C.B. 'D' SOCKET
J2 — 25 WAY 'D' PLUG

A1	74LS05
A2	74LS02
A3	74LS32
B1	74LS04
B2	74LS05
B3	47KΩ PACK
C1	74LS155
C3	74LS138
EC1	10μF. 25V
C2 - C6	10nF. 18V
R1	1KΩ
R2 - R6	8.2KΩ

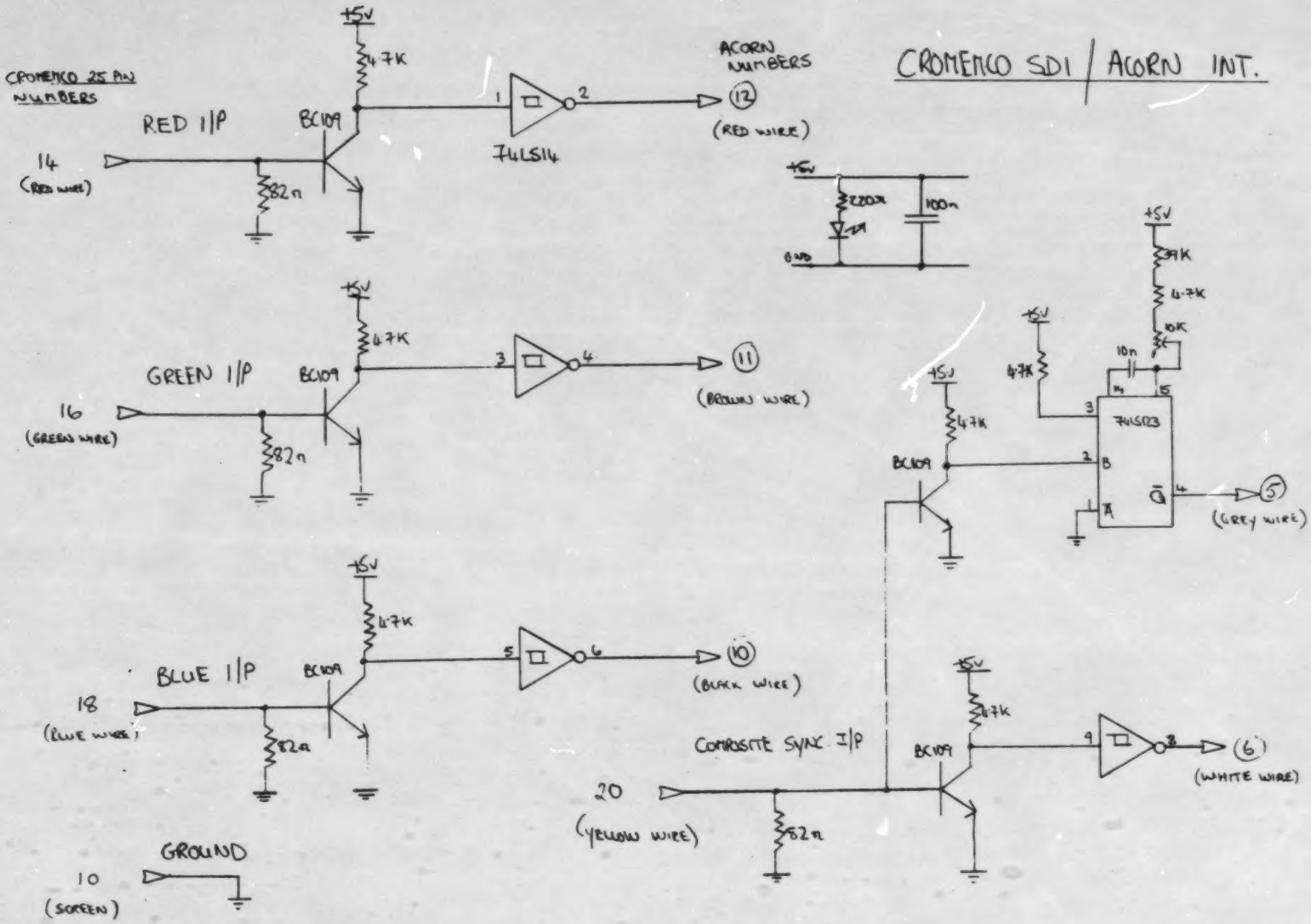
I.C	EDGE	J1	NAME
A1 - 2	G5	1	X_0 O\P
A1 - 4	G6	2	X_1 O\P
A1 - 6	G7	3	X_2 O\P
A1 - 8	G8	4	X_3 O\P
A_2 - 3	G9	5	Y_0 I\P
A_2 - 6	G10	6	Y_1 I\P
A_2 - 8	G11	7	Y_2 I\P
A_2 - 11	G12	8	Y_3 I\P
—	G9A	9	GND
A_3 - 12	G11A	15	Y_4 I\P

J1 CONNECTIONS

J2	EDGE	I.C.	NAME
3	W31	—	+5V
10	W6	A3-2	D6 I\P
11	W10	C3-3	D4 I\P
12	W14	C3-1	D2 I\P
13	W18	C1-13	D0 I\P
14	W1	—	GND
22	W4	A3-1	D7 I\P
23	W8	A3-5	D5 I\P
24	W12	C3-2	D3 I\P
25	W16	C1-3	D1 I\P

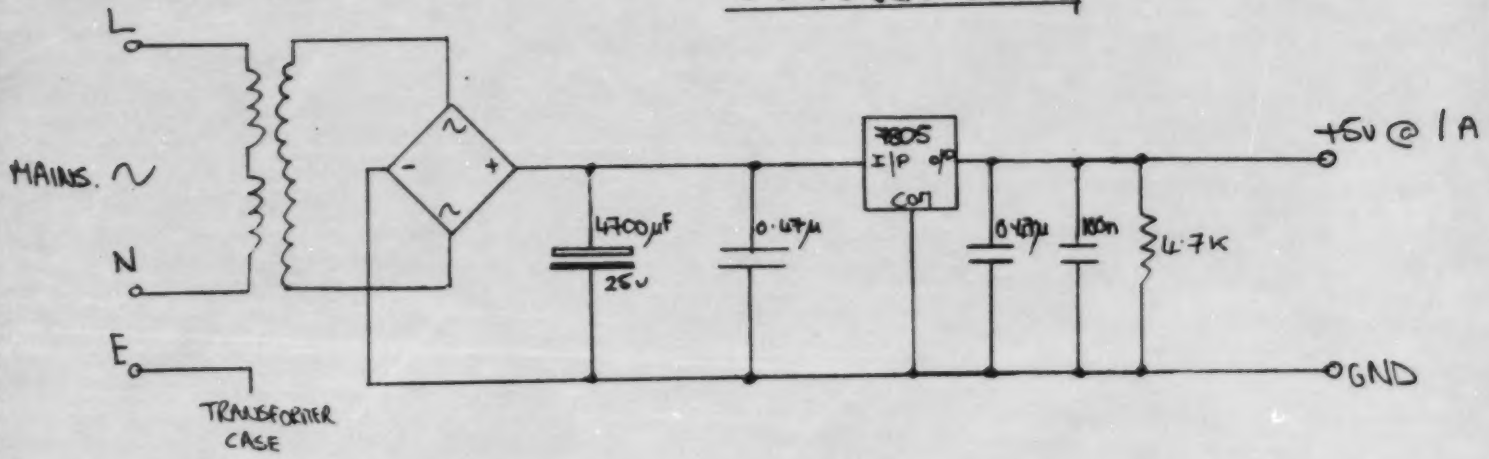
J2 CONNECTIONS

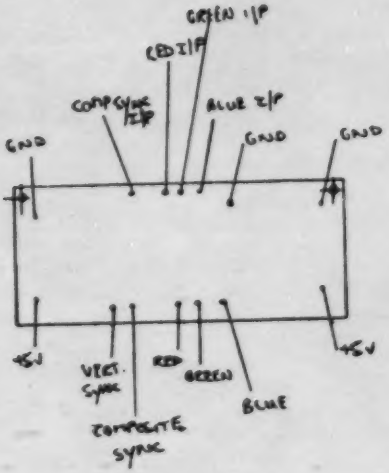
Cromemco SDI/Acorn Encoder Interface


CROMEMCO SDI / ACORN INT.
CROMEMCO 25 PIN NUMBERS
ACORN NUMBERS
RED I/P
BC109
4.7K
82n
14
(RED WIRE)
74LS14
12
(RED WIRE)
+5V
220R
100n
GND
GREEN I/P
16
(GREEN WIRE)
11
(BROWN WIRE)
BLUE I/P
18
(BLUE WIRE)
10
(BLACK WIRE)
GROUND
10
(SCREEN)
COMPOSITE SYNC I/P
20
(YELLOW WIRE)
6
(WHITE WIRE)
39K
10K
10n
74LS123
5
(GREY WIRE)

G-7

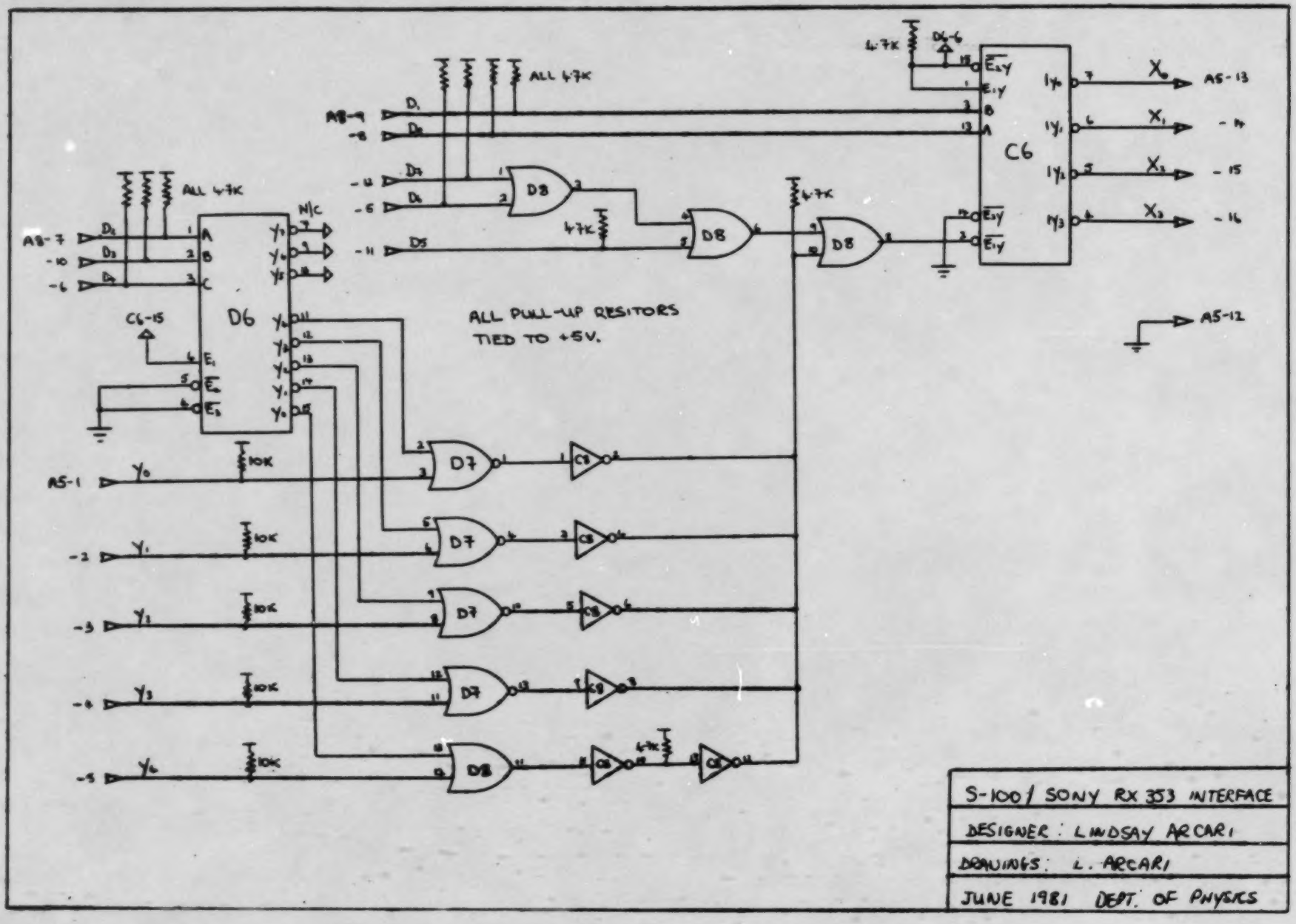
5V POWER SUPPLY

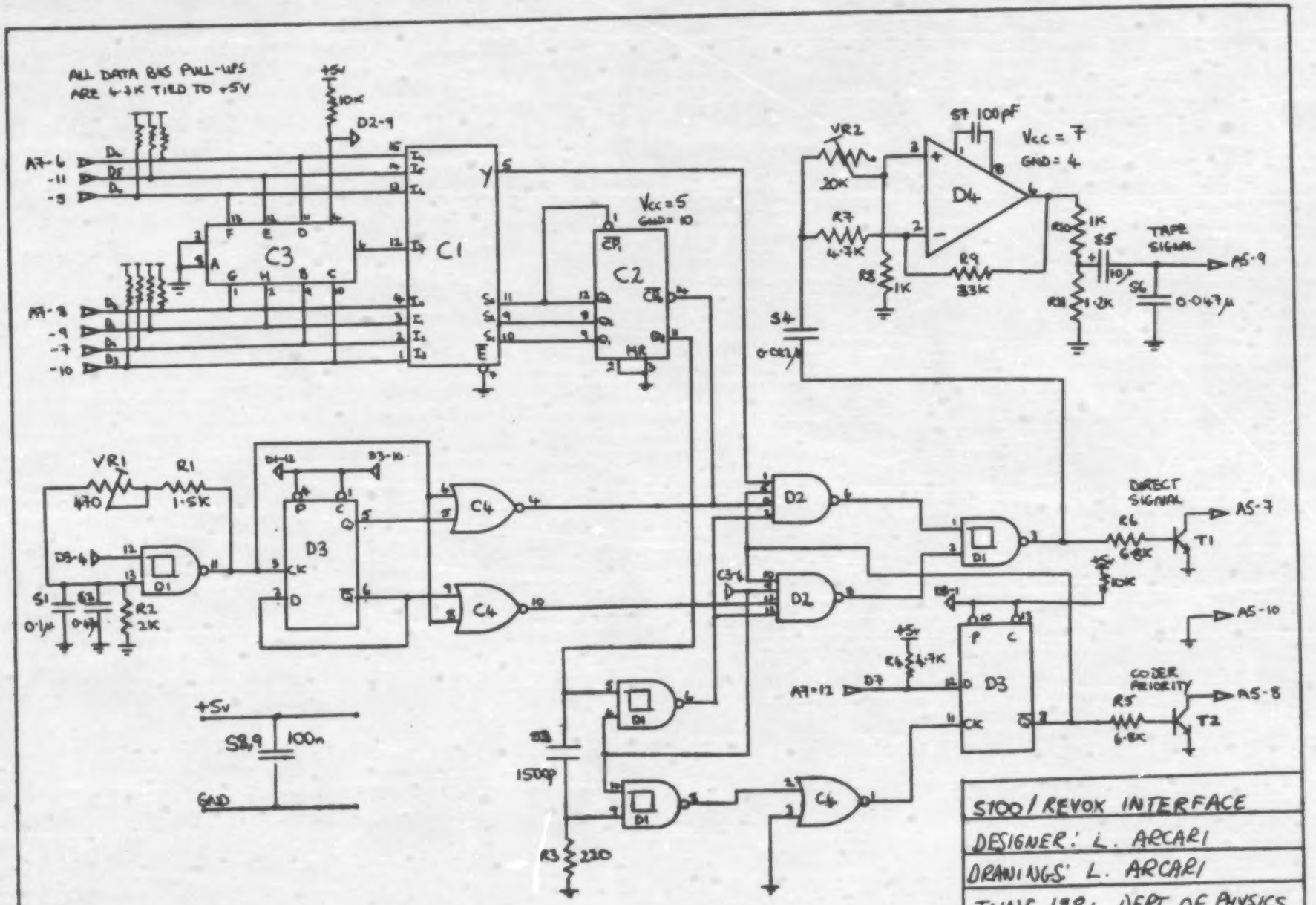




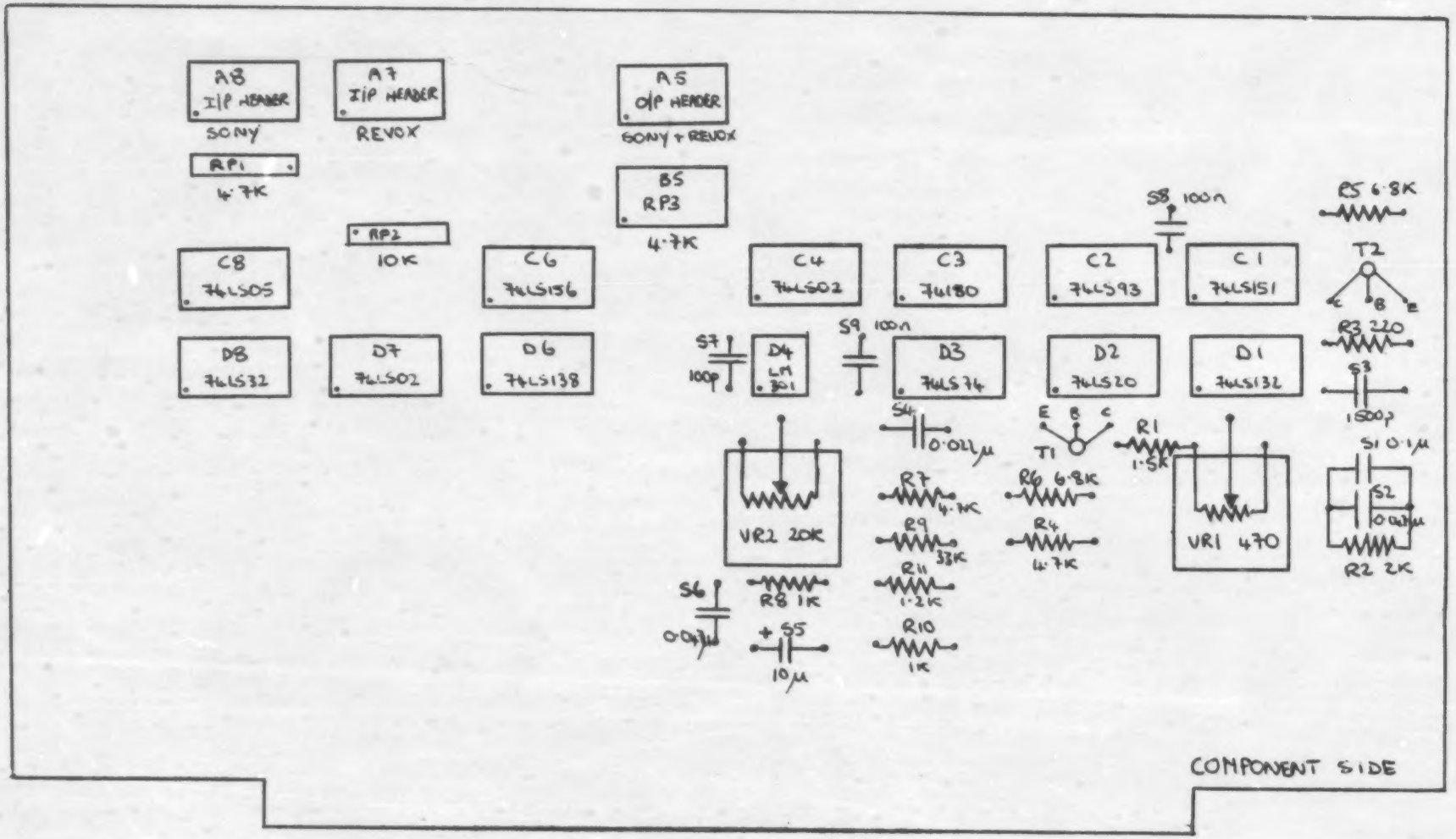
PIN DESIGNATIONS

Sony RX-353/Revox Microfiche/ Revox Audio/Cromemco System 3


ALL 4.7K
A8-9
-8
-11
-6
-5
A8-7
-10
-6
D6
N/C
C6-15
ALL PULL-UP RESITORS
TIED TO +5V.
4.7K
D8
D7
10K
A5-1
-2
-3
-4
-5
C6
X0
X1
X2
X3
A5-13
- 14
- 15
- 16
A5-12
S-100 / SONY RX 353 INTERFACE
DESIGNER: LINDSAY ARCARI
DRAWINGS: L. ARCARI
JUNE 1981 DEPT. OF PHYSICS


ALL DATA BUS PULL-UPS ARE 4.7K TIED TO +5V
+5V
10K
D2-9
A7-6
-11
-5
A1-8
-9
-7
-10
C3
C1
C2
Vcc=5
GND=10
VR2
20K
S7 100pF
Vcc = 7
GND = 4
D4
R7
4.7K
R8
1K
R9
33K
R10
1K
R11
1.2K
S5
TAPE SIGNAL
AS-9
S6
0.047µ
S4
0.022µ
VR1
470
R1
1.5K
D3-10
D1-12
D3
C4
D2
D1
S1
0.1µ
S3
0.47µ
R2
2K
DIRECT SIGNAL
R6
6.8K
T1
AS-7
AS-10
A7-12
D7
R4
4.7K
CODER PRIORITY
R5
6.8K
T2
AS-8
S8,9
100n
GND
S2
1500p
R3
220
S100 / REVOX INTERFACE
DESIGNER: L. ARCARI
DRAWINGS: L. ARCARI
JUNE 1981 DEPT. OF PHYSICS

G-10



A8 HEADER IS THE DATA I/P FROM THE T-UART TO THE SONY INT.
A7 " " " " " " " " " " " " REVOX "
A5 " ARE THE INTERFACE O/P'S TO THE SONY AND REVOX AND ALSO I/P'S FROM THE SONY TO THE SONY INTERFACE.

NAME	HEADER	J2
X_0	A5-13	1
X_1	-14	2
X_2	-15	3
X_3	-16	4
Y_0	-1	5
Y_1	-2	6
Y_2	-3	7
Y_3	-4	8
Y_4	-5	15
GND	-12	9

NAME	HEADER
D_0	A8-8
D_1	-9
D_2	-7
D_3	-10
D_4	-6
D_5	-11
D_6	-5
D_7	-12

S100/SONY CONNECTIONS

FUNCTION	O/P	J4
TAPE SIGNAL	A5 - 9	2
GND	- 10	3
DIRECT SIGNAL	- 7	4
CODER PRIORITY	- 8	5

J4 IS 25 WAY FEMALE 'D' CONNECTOR ON BACK OF CROMEMCO.

FUNCTION	I/P
D0	A7 - 8
D1	- 9
D2	- 7
D3	- 10
D4	- 6
D5	- 11
D6	- 5
D7	- 12

S100 / REVOX CONNECTIONS

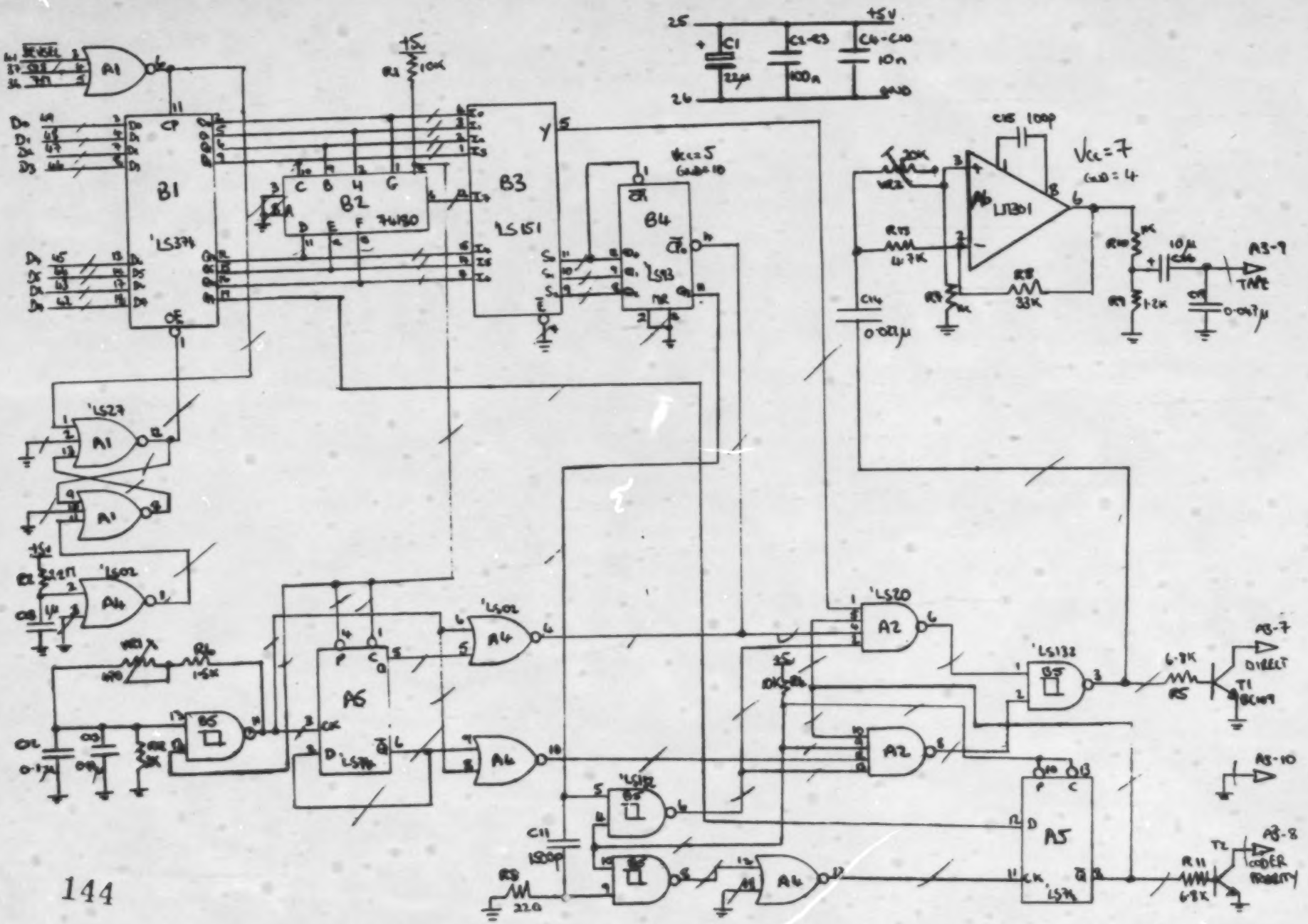
Sony RX-353/Revox Microfiche/
Revox Audio/Apple II

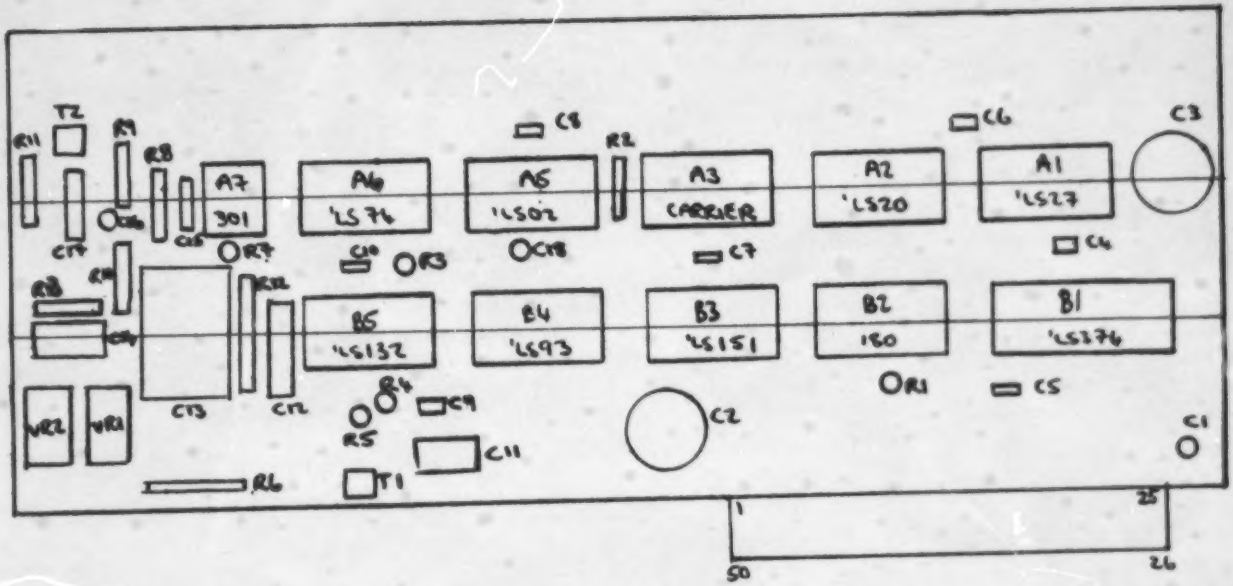
APPLE/SONY CONNECTIONS

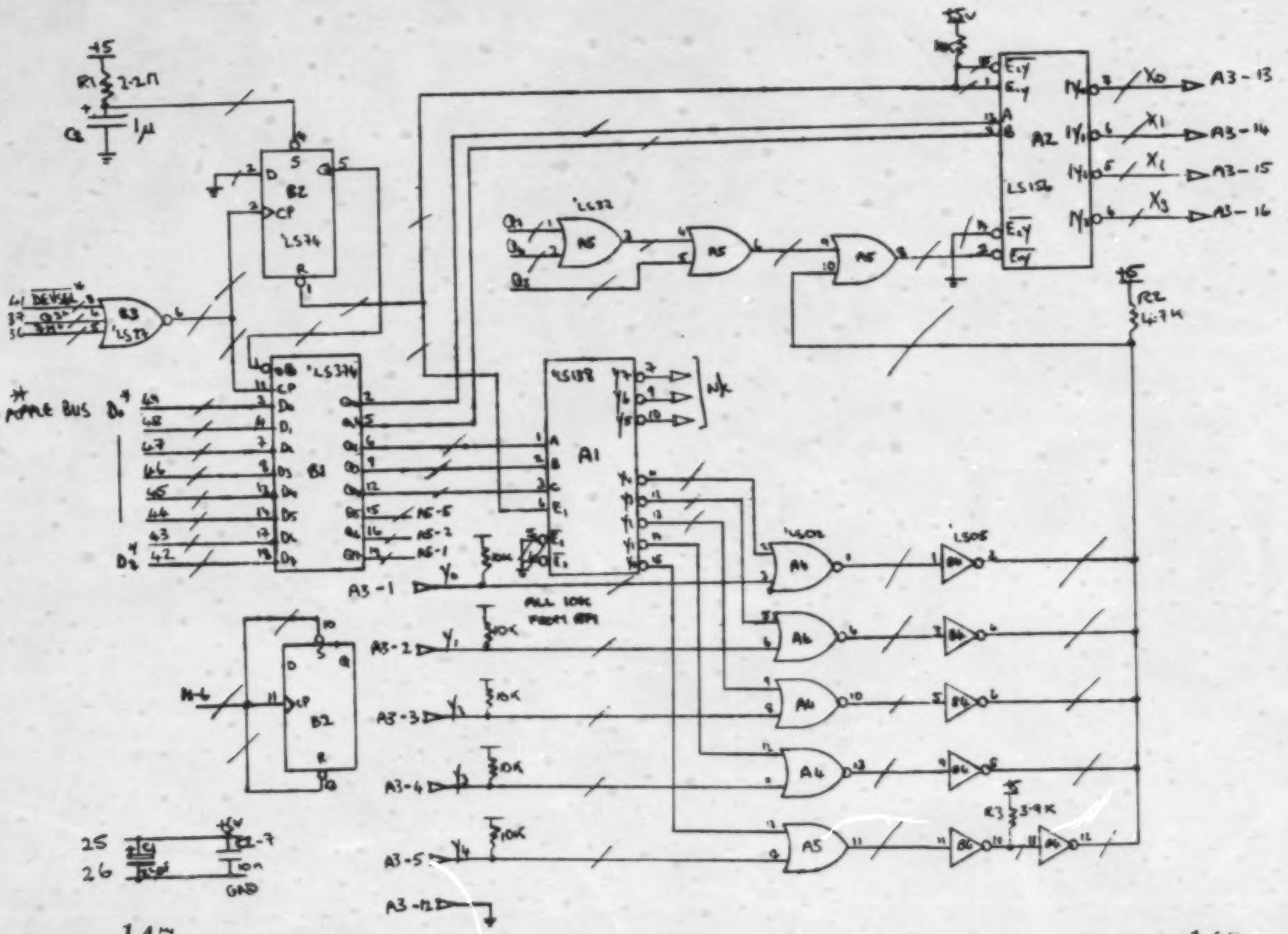
CANNON 'D'	HEADER (A3)	FUNCTION
1	13	X0
2	14	X1
3	15	X2
4	16	X3
5	1	Y0
6	2	Y1
7	3	Y2
8	4	Y3
9	5	Y4
15	12	GND

APPLE/REVOX CONNECTIONS

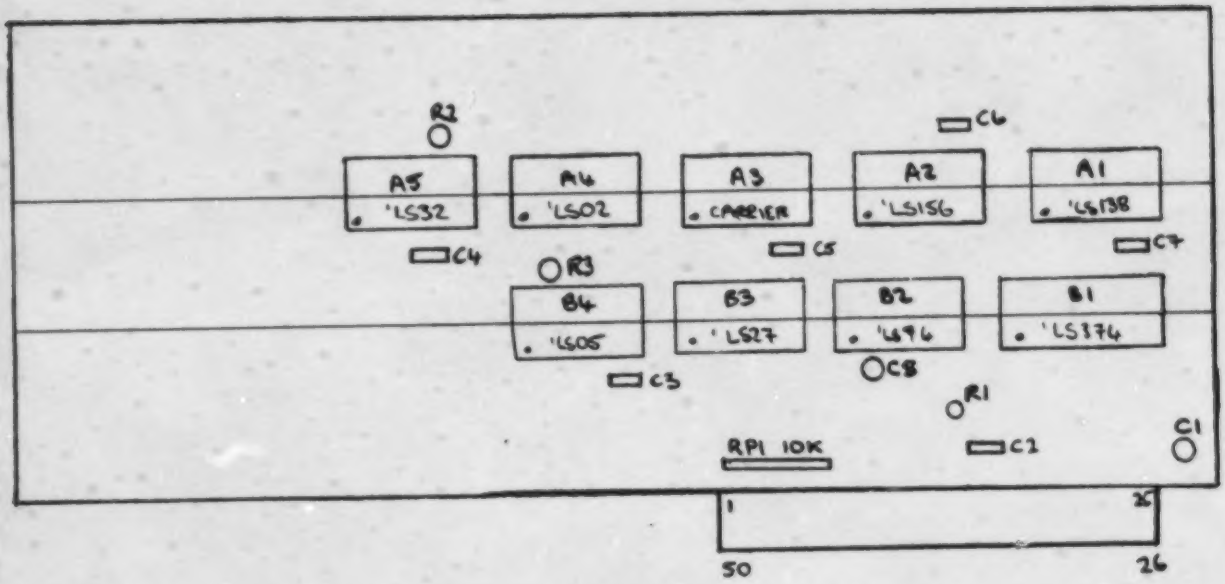
CANNON 'D'	HEADER (A3)	FUNCTION
2	9	TAPE SIGNAL
3	10	GND
4	7	DIRECT SIGNAL
5	8	CODER PRIORITY


B1
'LS374
B2
74LS30
B3
LS151
B4
'LS93
LM1301
'LS27
'LS02
'LS20
'LS132
'LS74
A1
A2
A3
A4
A5
A6
+5V
+12V
A3-7
DIBELT
A3-8
CODER POLARITY
A3-9
TAPE
A3-10

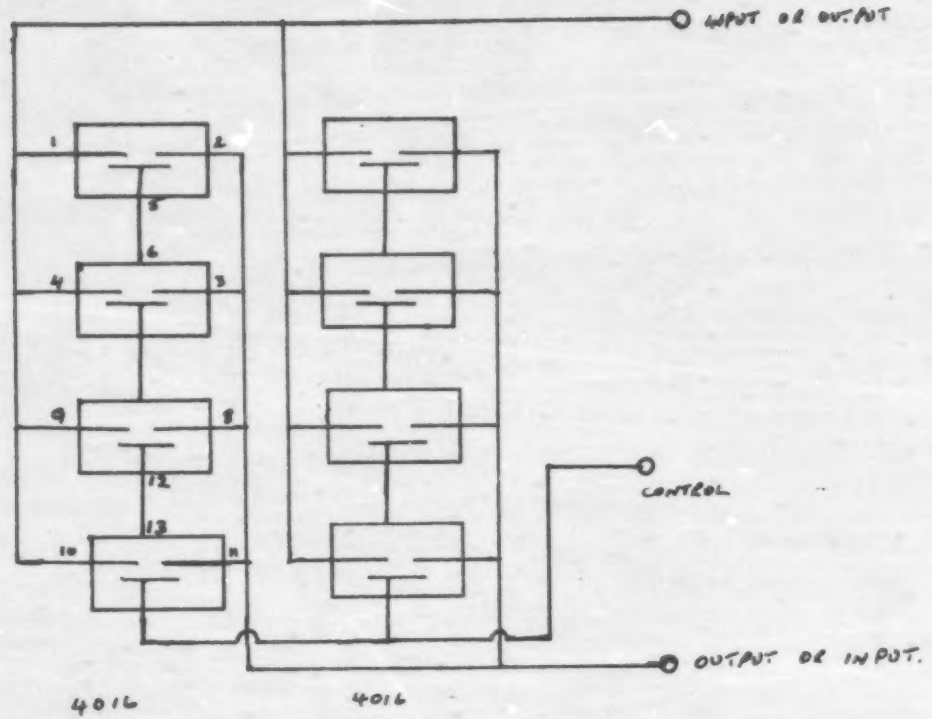

T2
R11
R9
R8
A7
301
A6
'LS 74
A5
'LS02
A3
CARRIER
A2
'LS20
A1
'LS27
C8
C6
C3
R2
C4
C10
R3
C18
C7
R7
C16
R10
R12
B5
'LS132
B4
'LS93
B3
'LS151
B2
180
B1
'LS374
R1
C5
C13
C12
R4
C9
C2
C1
VR2
VR1
R5
C11
R6
T1
1
25
50
26


+5
R1 2.2M
C2 1µ
B2
LS74
B3
'LS32
A5
A2
LS158
X0
X1
X2
X3
A3-13
A3-14
A3-15
A3-16
R2 4.7K
APPLE BUS
D0
D1
D2
B1
'LS374
A5-5
A5-2
A5-1
A3-1
A1
'LS158
N/C
ALL 10K FROM +5V
A3-2
A3-3
A3-4
A3-5
A3-12
A6
A4
A5
'LS05
R3 3.9K
25
26
B2-7
10n
GND

G-17


R2
C6
A5
'LS32
A4
'LS02
A3
CARRIER
A2
'LS156
A1
'LS138
C4
C5
C7
R3
B4
'LS05
B3
'LS27
B2
'LS96
B1
'LS374
C3
C8
R1
C1
RP1 10K
C2
1
25
50
26

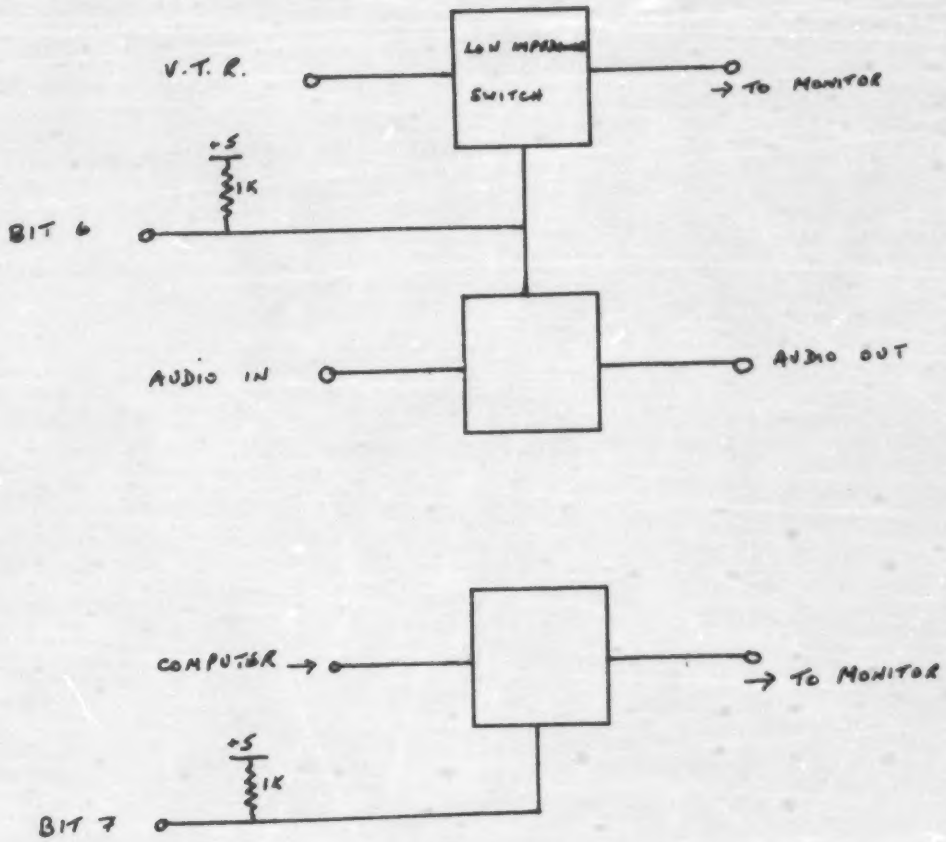
Video Switch Interface



G-19

LOW IMPEDANCE SWITCH.

2 4016 Quad switches are wired as shown to reduce the input impedance to < 50Ω.


V.T.R.
LOW IMPEDANCE
SWITCH
→ TO MONITOR
+5
1K
BIT 6
AUDIO IN
AUDIO OUT
COMPUTER →
→ TO MONITOR
+5
1K
BIT 7

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